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WEIGHT OF MINERAL RAISED YEARLY
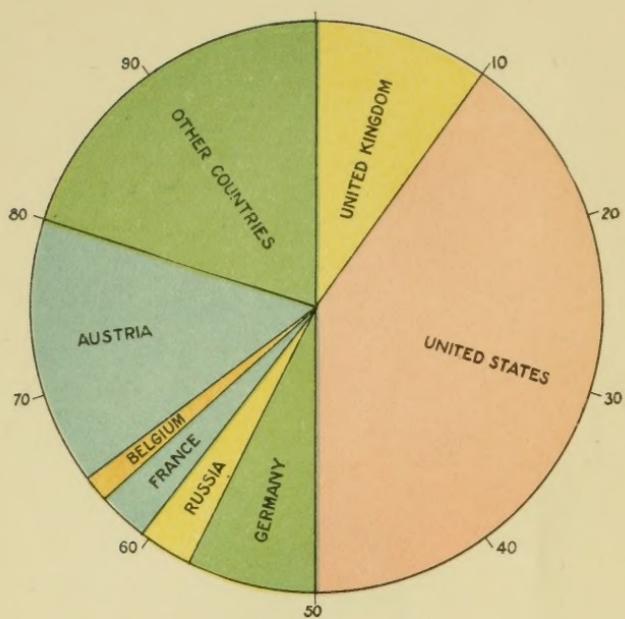
VALUE OF MINERAL PRODUCT YEARLY
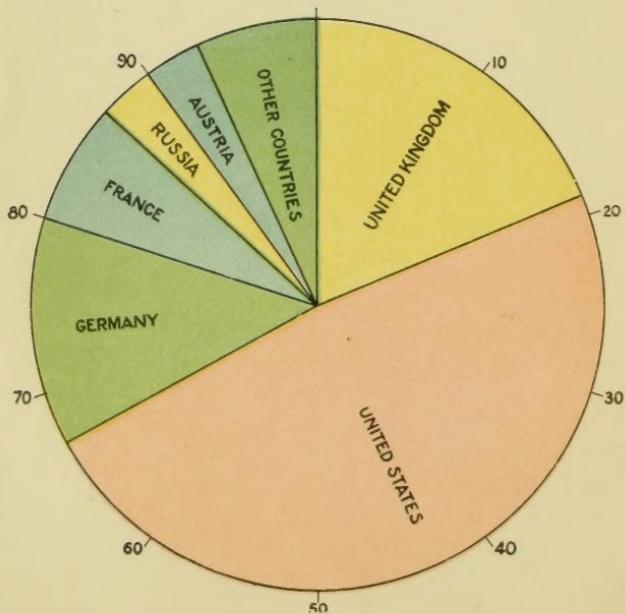
The
Making of America

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VOL. VI

Mining and Metallurgy

Checked

CONTENTS

VOLUME VI.

MINING AND METALLURGY.

CONTENTS

MINERAL RESOURCES OF THE UNITED STATES.

BY CHARLES KIRCHOFF.

[Charles Kirchoff, editor The Iron Age; born San Francisco, March 28, 1853; graduate Royal School of Mines, Clausthal, Germany; chemist Delaware Lead Refinery, Philadelphia, 1874-77; assistant editor Metallurgical Review, 1877-78; assistant editor Iron Age, 1878-81; managing editor Engineering and Mining Journal, 1881-84; associate editor Iron Age, 1884-89 and editor in chief since 1889; special agent of the United States Geological survey for lead, copper and zinc since 1883. President American Institute of Mining Engineers, 1898-99.]

When I was a boy I was taught that in this great country, as in fact in any land, an assured future lay with him who identified himself as closely as possible with the development of its natural resources; that the producer of the primary articles of necessity, the tiller of the soil and the miner, must under all circumstances find an outlet for their energies and a reward for their special skill and knowledge. To one born in the sight of the Golden Gate soon after the discoveries in California, the future held out vast possibilities to every searcher for treasure; yet the wildest dreams of the gold seekers of that day have been outdone by the subsequent discoveries of our mineral wealth, although now the yellow metal occupies a minor place when compared with the useful minerals.

It may be stated as a general proposition that to a civilized community the possession of mineral wealth is important almost in the inverse order of the unit value of the individual mineral. Cheapest and yet most important of all is coal and fuel, next iron, the baser metals, the precious metals, and finally the precious stones. Without the first named no great industrial expansion is possible, while the last named, however welcome, do not through their absence hamper growth.

It is not possible to speak with precision as to the extent of the mineral resources of any country, because new discoveries are made from time to time even in Europe, where exploration has extended over many centuries. It is certainly not possible in our own land, where much territory is still covered with dense forests and swamps and whole mountain

ranges have been untrod. Under the circumstances, comparisons are unsafe, but with such it is stating a fact that the United States has been blessed with almost unrivaled resources.

The geographical distribution of our mineral resources could be fairly well shown in maps and charts, so far as exploration and development have revealed them. We might in that way show our assets, territorially distributed, but we would create a very erroneous opinion of their real value. With the most important minerals the economic value of a deposit is dependent upon many other considerations besides those of mere size and extent. Conspicuous among these are accessibility to markets, the means of transportation, natural or artificial, the existence of a supply of labor and the character of that labor, climate, the character of the community, its laws, etc. These in their shifting influence find expression in the actual product, and that is a better measure of relative importance than mere location and extent.

The latter, designated on maps by coloring, is a poor guide since relatively unimportant deposits may cover a very extended territory. Coal measured may underlie many thousands of square miles, yet the seams which they enclose may not be numerous nor thick nor possess a coal of satisfactory quality. A field small in area, at some distant place, may be the scene of enormous operations, while the greater basin may hardly be able to supply local requirements. The anthracite coal regions, as to area, constitute only an exceedingly small portion of the known coal fields of the United States, yet their importance overshadows any other industrial district.

Useful minerals are found in deposits which may in general be classified, for the purpose of estimating them as assets, into two groups. First are those which are beds constituting one of a series of strata. They are usually persistent and fairly regular over large areas like the coal seams, and therefore permit of some estimate of their contents. Second are those whose origin is due to local circumstances, and these include the fissure veins. They are usually irregular, and it is in most cases entirely impossible to arrive at any conclusion of their extent and value without most elaborate under-

ground exploration or actual mining operations. It is therefore quite impossible to submit more than a very vague data relative to the magnitude of the mineral wealth of any country. In a very rough way we may do so, of course, so far as coal is concerned. How rough that is will be readily understood when the statement is made that out of an estimated coal area of about 4,650,000 square miles in the world, China is credited with 4,000,000 square miles. Our own country is put down at about 280,000 square miles, and this compares with 11,900 square miles for Great Britain, 1,770 square miles for Germany, 2,086 square miles for France, and 510 square miles for Belgium. Considering the enormous tonnage which the European countries named are furnishing from their relative restricted territory, our possible reserves look huge. Of course, areas are not a true measure of value or importance. Thus our Pennsylvania anthracite fields embrace a territory of only 468 square miles, and yet outdo in value probably any coal area of like extent anywhere in the world.

We must, therefore, leave to the imagination the pleasure of dealing with the magnitude of our mineral wealth. All we do know is that it is very great, not alone in its magnitude but also in its variety.

There is hardly a state or territory in the union which does not possess and is not utilizing mineral property, particularly when we include clays and stone and mineral springs. Maine has her granite and stone; Vermont her marbles, granite, and copper; Connecticut her iron ore; Massachusetts her granite, pyrites, and iron ore; New York, salt, stone, petroleum, natural gas, clays, cement, gypsum, graphite, and iron ore; New Jersey, clays, marls, zinc, and iron ore; Pennsylvania, petroleum, coal, iron ore, natural gas, cement, rock, and clays; Maryland, iron ore; Virginia, coal, iron ore, zinc ore, pyrites, and copper ore; North Carolina, gold, stone, corundum, mica, copper, and iron; South Carolina and Florida their phosphates; Tennessee, coal, copper, iron ore, and phosphate rock; Alabama, coal and iron ore; Louisiana, sulphur and salt; Kentucky has coal, iron, zinc, and lead; West Virginia, petroleum, natural gas, coal, and salt; Texas, petroleum, coal, iron ore, quicksilver and silver; Arkansas, zinc,

manganese, bauxite, whetstone, and coal; Missouri, lead, zinc, iron ore and clays; Ohio has coal, petroleum, natural gas, clays, grindstones, salt, and iron ore; Michigan, copper, iron ore, coal, cement, grindstones, clay, limestone, and salt; Illinois, coal; Indiana, natural gas, coal, petroleum, whetstones, and clays; Wisconsin, iron ore, lead, and zinc; Iowa, clays and lead; Kansas, lead, zinc, coal, natural gas, salt, and gypsum; Indian Territory, coal; South Dakota, gold, copper and lead · Wyoming, petroleum, coal, copper, salt and iron ore; Colorado, gold, silver, lead, copper, petroleum, coal, and iron; Utah, gold, silver, lead, coal, iron and sulphur; Montana, copper, silver, gold and sapphires; Idaho, lead, gold and silver; Oregon, gold, copper, and silver; Washington, coal, iron ore, lead, and silver; Arizona is famous for copper, silver and gold; New Mexico for coal, iron ore, copper, and silver; Nevada for silver, gold, and copper, and California for gold, copper, quicksilver, petroleum, borax, asphaltum, magnesite, and stone.

As the pioneers penetrated into our country they caught some glimpses of these treasures. The Jesuit fathers in the reports of their journeys in 1659 and 1660, mention the copper of Lake Superior, and Le Sueur, in his explorations of the Mississippi at the commencement of the eighteenth century noticed the lead deposits of that region. Copper was mined in Connecticut and in New Jersey, and iron manufacture began in New England and in Virginia at about that time, but it was not until the end of the eighteenth century that iron, lead, and copper mining were carried on on a fairly comprehensive scale. Coal was mined in the vicinity of Richmond from 1770 to 1780. In 1820 the first cargo of anthracite reached Philadelphia, while in 1833 and 1834 Virginia, North Carolina, South Carolina, and Georgia were in the zenith of a gold mining boom which resulted in an annual product of about $600,000. The year 1844 saw the opening of the Lake Superior copper region, and then in 1848 came the famous California gold excitement, followed by gold mining in Oregon in 1852, in Arizona in 1858, in Colorado in 1859, in Idaho and Montana in 1860. Iron mining on Lake Superior began in 1856. In 1859 came the discovery of the Comstock lode, which created an enormous activity in silver mining and led to the opening of

MINERAL PRODUCTION OF THE UNITED STATES
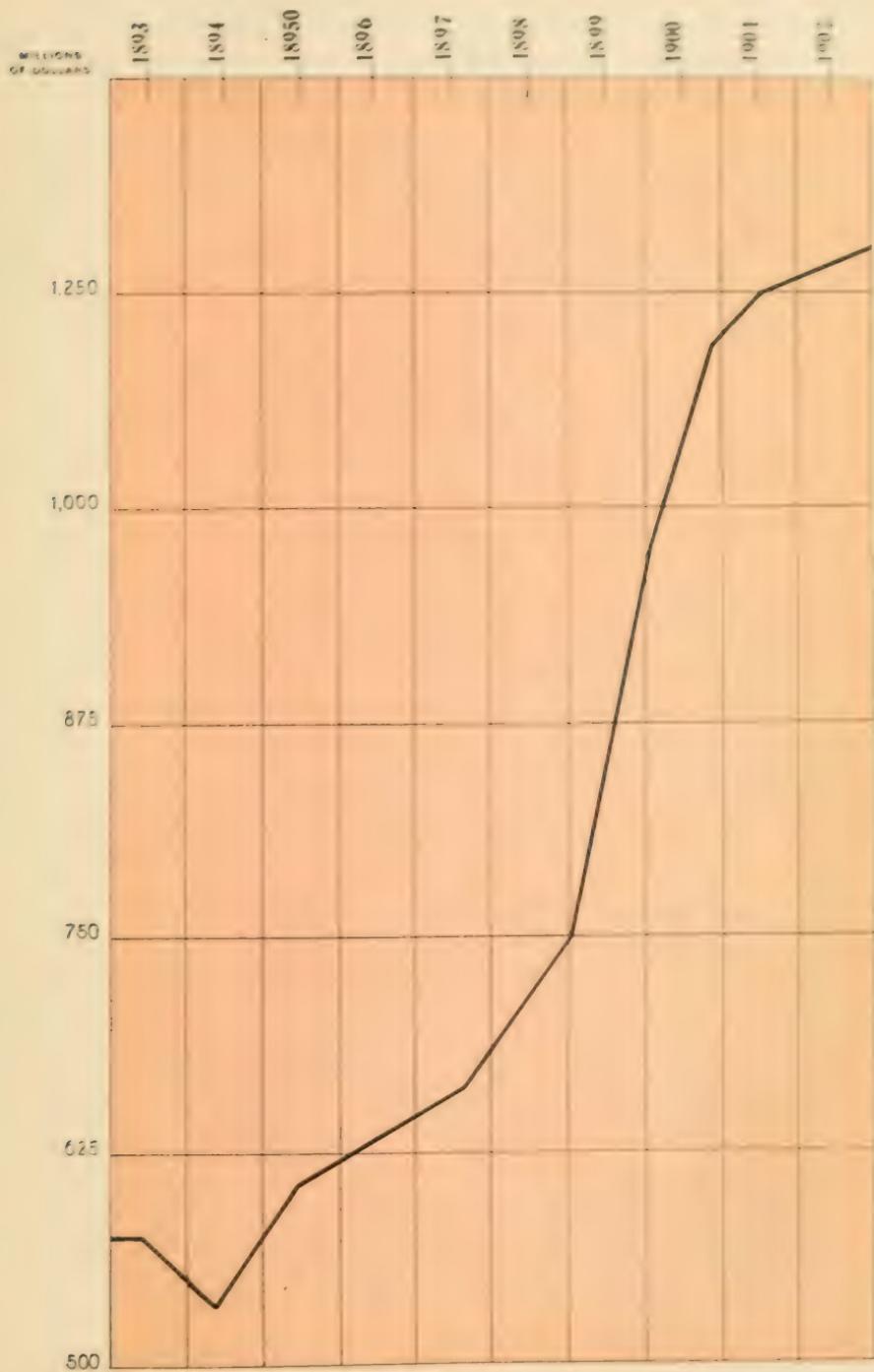
the Unionville, Kelso Run, Belmont, White Pine, Eureka, Esmeralda, and Pioche districts in Nevada, the Owyhee in Idaho, the Cottonwood and Bingham in Utah, and the silver districts of Colorado. The year 1860 brought the discovery of petroleum in Pennsylvania, to be followed many years later by the utilization of natural gas.

The development of the copper mines of Arizona began seriously in 1880 and 1881, with the opening of the Bisbee, Globe, and Clifton districts, to which later on the United Verde was added. Butte rushed into prominence at about the same time. Later in the seventies Leadville began to pour forth its mass of argentiferous lead.

It may be stated in a general way that enterprise did not seriously turn to the mining industry in this country until the second half of the last century, and that its greatest achievement has been crowded into the last thirty years. I do not propose to weary you with an endless array of figures. Suffice it to say that the value of the mineral product of the United States had risen to about $370,000,000 in 1880, and reached $620,000,000 in 1890, and according to the statistics collected by Dr. David T. Day of the United States geological survey, exceeded $1,400,000,000 in 1903. This includes $500,000,-000 for coal, $344,000,000 for pig iron, $91,000,000 for copper, $73,000,000 for gold, $94,000,000 for petroleum, $67,000,000 for stone, $33,000,000 commercial value, for silver, $35,000,-000 for natural gas, and $23,000,000 for lead.

We stand first as producers of coal, our output in 1902 having been 301,590,000 short tons, Great Britain following with 254,000,000 tons, and Germany with 165,000,000 tons, our percentage of the world's total being about 31 per cent. In petroleum we have been racing with Russia, occasionally first and sometimes second. In 1901 we furnished a little over 69,000,000 barrels to the world's total of 165,000,000 barrels, our percentage being 41.9 per cent, as compared with Russia's 41.5 per cent.

In the manufacture of pig iron we have now reached the point that our production is greater than that of our largest rivals, Great Britain and Germany, put together, with Bel-

gium thrown in. We manufactured in 1902 fully 40 per cent of the world's total.

The gold production of the world was about $325,000,000 in 1903, to which we contributed $74,000,000 and Australasia $77,000,000. Of course, when the Rand resumes its full production and again starts on its natural increase, we shall probably have to yield first place to it.

The world's production of silver had a commerical value of about $103,000,000. Here again we occupy first rank, with Mexico as a close second.

The supremacy in the copper mining industry is undoubtedly ours for many years to come. We produced over 52 per cent of the total of the world's annual yield of 512,000 tons. In 1902, with a product of 294,000 tons, we came close to the entire world's output in 1890, when it was 723,000 tons.

We stand in zinc following Germany. Our output of that metal in 1901 was 125,000 tons out of a total of the world of 501,000 tons, or over 25 per cent.

These figures, enormous as they are, do not really reflect adequately the great importance of our mining, since it lies at the foundation of the manufacturing industries of this country, and is the basis of its industrial greatness, backed as it is with an equally lavish supply of raw materials from the forest and farm. Mining and rail transportation have reciprocally aided one another, and in turn have contributed powerfully to the well being of the farmer and the lumberman.

As in other realms of material progress, the United States has outstripped all other civilized countries in the development of its mining and metallurgical industries.

Brief though the period be during which we have been actively mining, we have witnessed the exhaustion of famous great deposits and the decline of entire camps and districts. This is apt to occur most rapidly in case of placers, conspicuous among which are the auriferous sands and gravels in which the precious metal has been concentrated by the washing action of streams. California's enormous gold production of the early days fell off rapidly after the first decade of the working. The exhaustion of the silver-gold bonanzas of the Comstock lode, the rapid collapse of the mining of silver lead

VALUE PER SQUARE MILE OF MINERALS PRODUCED
BY STATES AND TERRITORIES

LESS THAN $50

$50 TO $100

$100 TO $500

$500 TO $1,000

$1,000 AND OVER
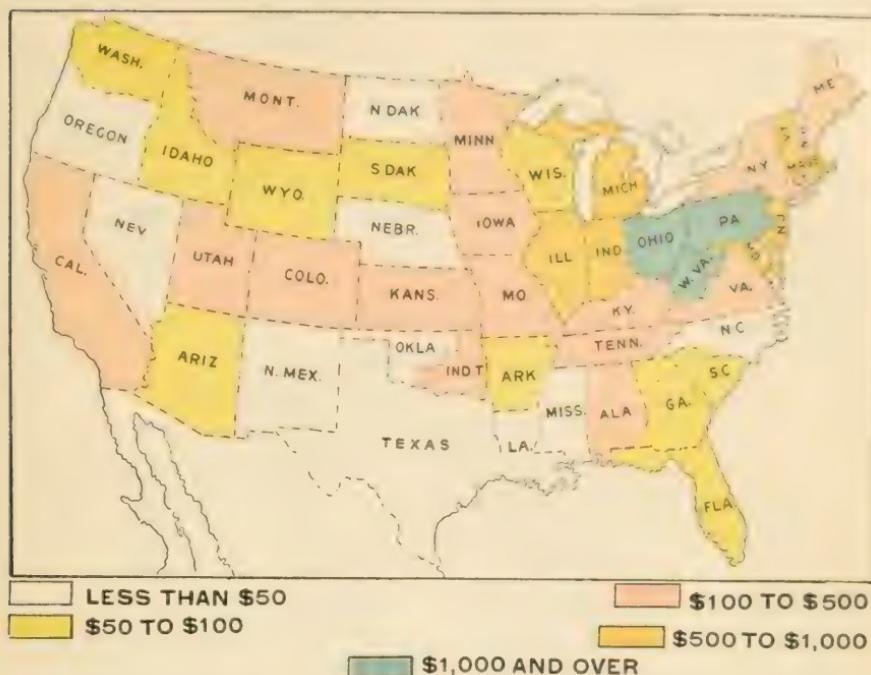
PROPORTION OF MINERALS PRODUCED BY GEOGRAPHIC DIVISIONS

PER CENT

0

20

40

60

80

100

NORTH ATLANTIC DIVISION

SOUTH ATLANTIC DIVISION

NORTH CENTRAL DIVISION

SOUTH CENTRAL DIVISION

WESTERN DIVISION
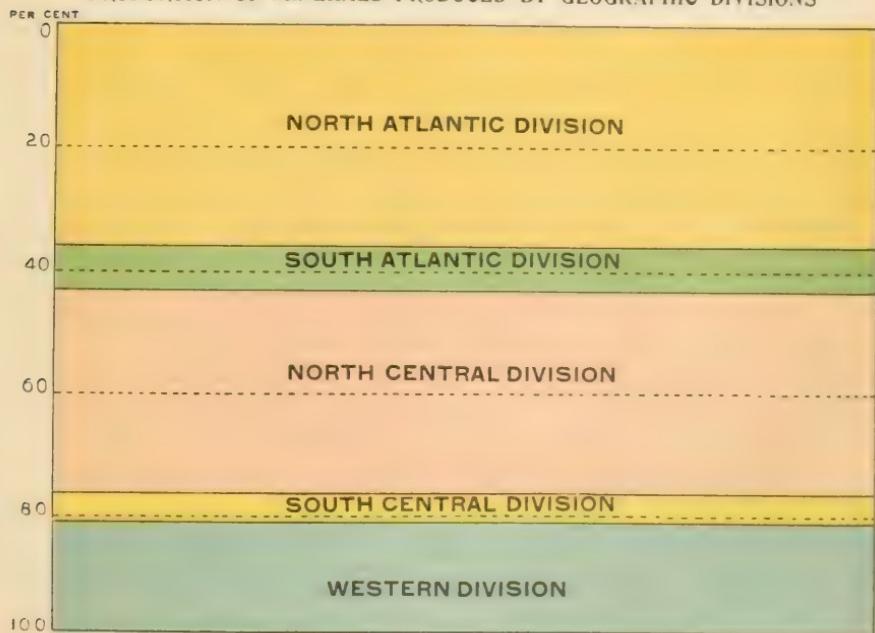
ores of the Eureka district in Nevada, the practical cessation of working of once exceedingly productive quicksilver mines of California, are a few instances which could be multiplied. Yet thus far we have again and again witnessed the rapid rush into prominence of new districts. Thus Cripple Creek in Colorado recorded its first shipment of gold in 1891, the amount being estimated at $2,000. Two years later it was $2,000,000, in 1897 it crossed the $10,000,000 mark, and in 1900 had risen to $18,000,000. Butte in Montana was a silver camp of some importance twenty years ago, when copper was discovered and the district suddenly loomed up with exports by the ship cargo of 30 per cent ores to the astounded smelters of Swansea, Wales. When Leadville's great reserves of oxidized silver lead ores began to show signs of exhaustion, the Coeur d'Alene county, Idaho, rose to more than fill the gap.

Again and again we have faced the possibility that our petroleum supply would ultimately fail us; yet as the derricks fell into ruins in one field they rose like magic in others, the most startling recent instance being the opening of the California, Texas and Kansas fields. Some uneasiness has been felt as to the future of the lake iron ore supply. The Marquette district was in full development when the Menominee was opened out. Then came in rapid succession the Gogebic, and the Vermilion ranges, and finally, as the climax of all the Mesaba range. Again and again the prediction was made that the old Marquette range would show evidences of exhaustion, and yet year after year new mines have taken the place of old ones. New reserves are being opened up in all the districts until this generation may well dismiss any fears of future supplies, even taking into consideration that the demands are rapidly increasing year after year.

As for our resources of coal, the most important of our minerals, we are not likely to have a coal exhaustion commission, like that of our British friends, for centuries to come.

Our record of feverish activity is one of which we have every reason to be proud, but it must be acknowledged that it has been accompanied by serious abuses. In the rush to get rich we have deliberately followed the principle that it pays to waste. Within certain limits that may be economically

justifiable. In a new country, without adequate transportation facilities, high labor, and difficult surroundings, it is possible only to select the best and the richest, but unfortunately in mining that process of selection in most cases practically renders unavailable for the future that which has been rejected. Much of it is forever lost to the world, and what can be saved at a later date can be recovered only at a greatly increased cost. In the early days of our mining we have been unskillful, and even to-day we are robbing nature's storehouses of treasure, often destroying more than we utilize. At one time, not so many years since, barely one third of the anthracite coal in our beds finally reached the consumer. The other two thirds were lost in mining and in preparation for market.

It is characteristic of a great many of the mineral deposits that the mass of the ore, particularly with growing depth, is low in grade, the useful mineral being disseminated in relatively large quantities of barren rock. Very often the rich ore occurs only in streaks and pockets which constitute a minor percentage in the total amount of valuable material. In hunting for them the poorer material is rejected, although it may be close to the border line of profitable extraction. With improved economic conditions there is greater opportunity, and with greater skill and a broader comprehension there is a growing tendency among managers to rely more and more upon a moderate return of the large bodies of poor ore, accepting the occasional bonanza as a welcome addition to revenue. The reckless hunt for rich streaks is giving way to systematic utilization of a maximum of the deposits. It may not be as merry and exciting a life, but it is certainly a longer and happier one. There has been a great improvement in this direction in this country. It should be stated, however, that we can never hope to utilize the entire contents of a deposit. Still there can be no doubt that we have paid dearly in wasted resources for the achievements of opening them up so rapidly.

We have no particular grounds for mere pride of possession in our magnificent resources. Our glory, from a national point of view, should be completeness of utilization, and that

PRODUCTION OF PRINCIPAL MINERALS: 1902

MILLANS OF DOLLARS

Mineral	
COAL BITUMINOUS	
GOLD AND SILVER	
COAL ANTHRACITE	
PETROLEUM	
IRON ORE	
COPPER ORE	
NATURAL GAS	
LIMESTONES AND DOLOMITES	
CEMENT	
SILICEOUS CRYSTALLINE ROCKS	
LEAD AND ZINC ORE	
SANDSTONES AND QUARTZITES	
SLATE	
MARBLE	
PHOSPHATE ROCK	
BORAX	
GYPSUM	
CLAY	
QUICKSILVER	
TALC AND SOAPSTONES	
SULPHUR AND PYRITE	
GRINDSTONES AND PULPSTONE	
SILICA SAND	
MINERAL PIGMENTS, CRUDE	
PRECIOUS STONES	

has at times suggested the nationalization of our mineral industry, with the object of checking the abuses referred to. It may be doubted whether our practical good sense will ever allow that question to come to the front. The nation as such has only control now of these mineral resources which lie dormant in the national domain. In order to encourage their development, ownership is surrendered under easy conditions to the discoverer. That policy has unquestionably fostered enterprise in the past, but it is an open question whether the time is not approaching when the nation at large must assume the attitude of some state governments and of all private owners of mineral lands. These demand a royalty which may become an important source of revenue, and they generally produce what is more important to the nation, that the mine shall be operated in a workmanlike manner. The present generation has responsibilities to future generations. In their behalf it has the right and the duty to demand that the nation's gifts be not wantonly destroyed; that every means which engineering skill suggests be exhausted; that every reasonable precaution be taken to preserve from destruction useful mineral which, while not profitably available now, may become highly precious to future generations.

Nor should title to mineral property on the public domain be given without some provision for its surrender as the penalty for long continued idleness. It should revert to the nation, when after reasonable opportunity the discoverer is either unable or unwilling to utilize nature's bounty.

The United States has been exceedingly generous in throwing open mineral resources. It has been a wise policy, which the results on the whole have thoroughly justified. But conditions have changed greatly. The opening up of our mineral resources has ceased to be the hazardous undertaking it once was. Their utilization has become an undertaking in which engineering skill can more readily guarantee results. The splendid work of the U. S. Geological Survey has brushed away many uncertainties. The development of our great railway system has lessened costs, and cheaper and more confident capital has become a willing handmaiden to enterprise. The time is therefore approaching, if it is not now

at hand, when the nation is justified in imposing conditions not hitherto warranted. Conspicuous among these should be a rigid enforcement of the obligation to put a stop to wanton waste.

In the last few years a good deal of alarm has been felt that very dangerous monopolies may be created through the control of our mineral resources by powerful consolidations of capital. At the first blush, in studying the magnitude of those resources, we may feel inclined to dismiss the danger as remote. It assumes a somewhat different aspect, however, when we begin to differentiate. The conditions affecting the industrial utilization of mineral property vary greatly, and a closer study reveals the fact that a relatively small number of the deposits, through favoring circumstances, give their possessors special advantages. The deposits may be exceptionally rich or extensive, particularly pure, or may be so located with reference to the markets that they are capable cf yielding an adequate supply at a cost far below others. These advantages may represent enormous sums, and can therefore be capitalized correspondingly. Unless those who control them extort undue returns, measured by earning capacity, the owners of the other less favorably located deposits cannot compete and live. Of course, the risk is always run by those who secure control of the best of the mines that new deposits as valuable may be discovered elsewhere, just as those who utilize monopolies based upon patents take the chance that inventive genius, stimulated by opportunity, made exceptionally artificial, find means to dispute exclusive possession. There may be iron ore deposits as rich and as great as any on the Lake Superior ranges in the Rocky mountain region, yet for a generation to come they might as well be non existent, so far as the controlling position of the United States Steel corporation is concerned. An enormous power for good or evil may be wielded by groups of capitalists who control the commercially available mineral resources, though they constitute only a small fraction of the total assets of mineral wealth of the country. The fact that in most cases the earning capacity of these consolidations has been rated exceedingly high, furnished a premium on the

VALUE OF PRODUCTS OF PRINCIPAL MINERALS

MILLIONS OF DOLLARS

| | 0 | 80 | 160 | 240 | 320 | 400 | 480 | | | |

ALL MINERALS

COAL BITUMINOUS
GOLD AND SILVER
COAL ANTHRACITE
PETROLEUM
IRON
COPPER
ALL OTHERS
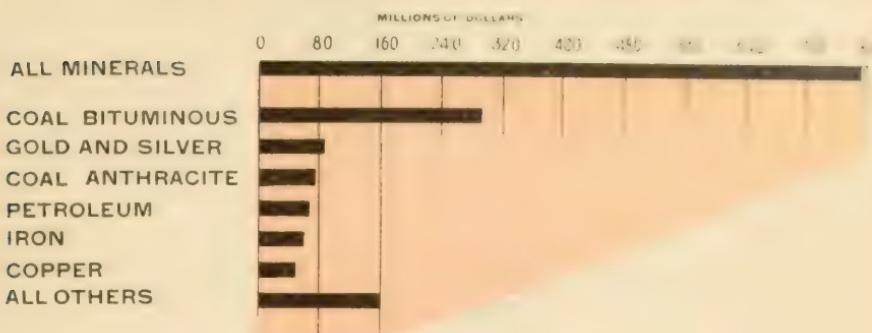
PROPORTION EACH BEARS TO TOTAL

PER CENT

0

COAL BITUMINOUS

25

COAL ANTHRACITE

60

GOLD AND SILVER

PETROLEUM

IRON ORE

75

COPPER ORE

ALL OTHERS

100
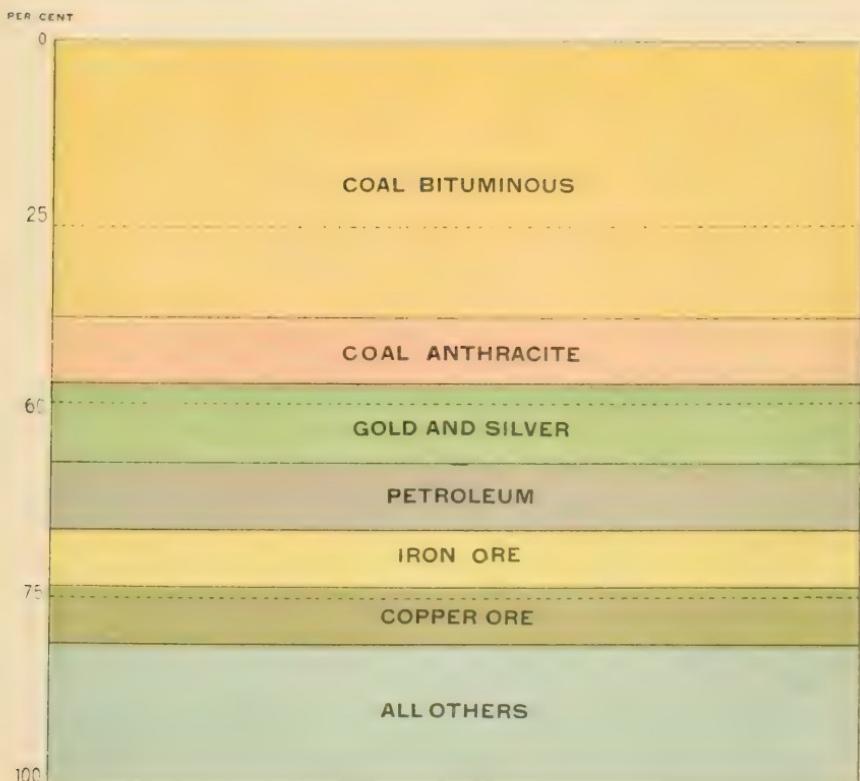
development of hitherto neglected deposits, and thus constitutes the greatest source of danger to the stability of many of these giant undertakings. What is perhaps to be most deplored is that these organizations, on their present basis, impose upon the industries dependent upon them a burden of fixed charges which must handicap this country in its struggle for an increasing share in the world's markets.

While the record of the achievements in mining, quantitively, has been extraordinary in this country during the past fifty years, we may look back with even greater satisfaction upon what has been accomplished qualitively, if we may so term it. It cannot be stated in an array of figures, but constitutes even greater glory to the captains of industry and the engineers and inventors who deserve the credit for it. It is expressed in the more complete utilization of the natural resources, as in the increase in the total extraction of the contents of a coal bed. It is in evidence in the capacity to utilize bodies of ores lower and lower in grade. It is proven by ability to produce from rebellious or impure ores metals nearly chemically pure and commercially available for a wider and wider range of consumption. It is measured by an expansion of markets which may be due to the fact that technical progress has proceeded more rapidly in our country than in others.

While it is true that in these early days our miners and smelters rose to the occasion when they were called upon to meet special conditions, the general fact is apparent from a study of our development that generally we first copied and then adapted the methods approved by experience in Europe. There were some very notable exceptions. We were forced to and did create hydraulic mining to collect the gold from alluvial deposits. We developed the preparation for anthracite for the market. We had nothing to guide us in the handling of the native copper rock of Lake Superior. The Washoe process was worked out to treat the silver ores of the Comstock lode. There were no precedents for methods in the petroleum industries and we had to learn by ourselves how to collect, distribute, and utilize natural gas. We taught the world how to use the steam shovel in mining. We have pushed the

development of the rock drill in mining and quarrying, and in more recent years have been in advance of all countries in the employment of modern coal cutting machinery. Still it is a fact that Cornish, Welsh, and English miners long controlled the working out of our mining methods, and that German and English metallurgists guided our first steps in utilizing our more complex silver, lead, and copper ores.

One of the most brilliant reports on the state of the art ever written, that of the late Abram S. Hewitt on the Paris exposition of 1867, is a confession of superiority of European method in iron manufacture, which is almost staggering to one who reads it in the light of the present day. I cannot help feeling that the recognition of our indebtedness to European practice in the earlier days should be insisted upon, since it is becoming altogether too common to assume that we are the chosen people so far as the mechanic arts are concerned. That feeling is so often encountered that the fear of the danger of over confidence is naturally aroused.

A striking fact is the growing interdependence of the various branches of the mechanic arts as contrasted with the conditions prevailing 25 years ago. The one relies upon the other, not alone for its products, but is aided too by suggestion and support. The metallurgist's progress is accelerated by the mechanical engineer, and the latter looks to the former for increasingly strong and reliable materials. The electrician has greatly widened the capacity for improving methods on the part of the copper producer, and in turn is under a debt to the copper miner, and the achievements of the rail maker are returned in kind by the railroad builder, who has taught both much of value in transporting materials. Thus all are shoulder to shoulder in the march of progress, mutually helpful and united—all powerful.

To a constantly increasing degree pure science, primarily in search of the truth for its own sake, sheds its searchlight along the path and has become a closer and more valued ally year by year. The majority of active workers looked askance at this meddler, preferring to allow their own fancy full sway whenever they stopped to seek for causes or explanations. Practical men may sometimes become impatient

VALUE OF MINERALS PRODUCED IN EACH STATE AND TERRITORY

MILLIONS OF DOLLARS

0 20 40 60 80 100 120 140 160 180 200 220 240

PENNSYLVANIA
OHIO
MICHIGAN
WEST VIRGINIA
COLORADO
ILLINOIS
CALIFORNIA
MONTANA
INDIANA
MINNESOTA
MISSOURI
ALABAMA
NEW YORK
UTAH
ARIZONA
KANSAS
IOWA
TENNESSEE
KENTUCKY
IDAHO
MARYLAND
TEXAS
SOUTH DAKOTA
VIRGINIA
NEW JERSEY

VERMONT
WYOMING
WASHINGTON
MASSACHUSETTS
WISCONSIN
INDIAN TERRITORY
MAINE
NEVADA
GEORGIA
FLORIDA
ARKANSAS
NEW MEXICO
OREGON
SOUTH CAROLINA
CONNECTICUT
NEW HAMPSHIRE
NORTH CAROLINA
RHODE ISLAND
DELAWARE
NORTH DAKOTA

when the laborious and apparently hypercritical methods of the scientist do not more promptly clear an obscure point for successful new lines of work, but the day has long passed when research was treated with grudging respect, if not with open hostility. No one is now readier to acknowledge his indebtedness to the chemist or the physicist than the manager or the practicing engineer. The fear is disappearing of impracticable science on the one hand, and of unscientific practice on the other.

The mining industry has suffered and, unfortunately, will suffer particularly in its relation to labor, from one apparently trifling circumstance, and that is the impression which a visit to underground operations makes upon the average layman. To be dropped suddenly into the dark depths with only a flickering candle to guide the uncertain steps, appalled by the dead silence or alarmed by strange noises, the rumble of the distant car, the reverberation of a shot far away, the rushing of unseen streams of water—the visitor is impressed with a sense of insecurity and danger. The bright sunlight has never seemed sweeter to him than upon his return to the surface, and if he happens to have access to the columns of the press he describes in lurid language the awful experience which incidentally convinces him that he is braver than he gave himself credit for in his innermost heart. Mining in the popular mind becomes one of the most hazardous of callings, when as a matter of fact, there are many others above ground which involve greater risks. With some exceptions, of course, the conditions which surround the work of the miner are rather favorable. He is not exposed to the rigors of the elements, and particularly during the last few decades the hygienic conditions have been brought to a high standard.

It is a fact that progress during the last 50 years has been pushed along lines even more important in their way than the increase in tonnage, the cheapening of product, or the raising of the standard of quality. The captains of industry in mining have, like others, displayed increasing care of their armies of men.

It has become an axiom with every enlightened manager that every means which shall render more satisfactory the

surroundings of the worker is bound to tell upon the results of their labor.   A comparison of our modern mines and plants with those of former decades, of which some even now survive, proves what attention is paid to making the conditions under which manual labor is performed as tolerable as the circumstances will permit.   There has been a tremendous improvement in this direction, and it does not lessen the achievement when we frankly acknowledge that it is largely due to the recognition of the fact that progress in this direction pays handsomely.

Let me go a step further, and that is to make the claim that the crowning glory of the efforts to improve our mining and metallurgical industries has been that they have contributed their full share to the development of this materialistic age.   They have helped to bring within the reach of an ever growing circle of people not alone the necessities, but also many of the comforts and some of the luxuries of life.   Let me confess that it seems to me the greatest and most commendable of achievements to raise ever so little the mass of humanity in civilization, and that is what progress in the mechanic arts during the past century has accomplished in a striking manner.   Start the masses on a higher plane— level them up.   The great genius may not tower so far above them as once he did; but that is a gain in harmony with our democratic institutions.   Let there be an increasing equality of opportunity, even though it makes the struggle fiercer and fiercer, if only public conscience will demand with sterner emphasis that the methods of achievement be lawful and fair.

PERCENTAGE OF INCREASE IN LAST DECADE

AMERICA'S UNDERGROUND WORKERS.

BY CHARLES HIGGINS.

[Charles Higgins, publisher; born Brooklyn, N. Y., 1860; educated in public schools of Brooklyn and Toronto, Canada; began business career as publisher in the latter city and removed to Chicago in 1878; has had editorial supervision of a number of important works among which may be mentioned The Americanized Encyclopedia Britannica, The World's History and Its Makers, and has written several articles for magazines and reviews.]

Blasting and tunnelling a way through the ground, far beneath the upper crust of the earth, sometimes fighting floods and again working in a heat that almost boils water, facing perils amid darkness, yet never halting winter nor summer nor admitting defeat, a great army of more than 600,000 men and boys is toiling in the mines of America, adding to the world's wealth daily by enormous contributions.

It is an army composed of representatives of every nation almost in the world, but a thoroughly Americanized army of men whose slogan is the same now as when it was first uttered by John Mackay, one of the promoters and owners of the Comstock mine in the Virginia range, Nevada, in 1859, when he said:

"Everything is possible in mining; the only question is, will it pay?"

With this spirit animating the men at the heads of the mines and extending down to and through the ranks to the boys in the breakers, America is foremost in the ranks of the mining countries of the world. Of its miners probably not more than half are Americans by birth; the rest are gathered from every nation of Europe and parts of Asia and Africa. There is not a state in the union, with a few exceptions, that is without mines and miners, and a great army could be mustered from the coal mines alone of the country, which cover more than three hundred thousand square miles of territory.

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ores, in coal and salt and minerals, every year, suffices to form pyramids besides which those of Egypt would fade into insignificance. The census for the last decade shows that, during the last year of the ten, this great army of underground laborers added to the world's stores something more than two hundred and twenty eight million tons of coal; eighty million tons of iron ore; copper ore that, when reduced, yielded more than two hundred and ninety thousand tons of copper, two hundred and seven thousand tons of lead, and nearly a hundred and thirty thousand tons of zinc. In addition the salt yield from the country's mines was two and one half million tons.

The gold mines gave up to the insistent and tireless workers ore that yielded $70,096,021 worth of gold bullion and the silver mines yielded ore that gave $34,036,108.

In addition to all this the yield of cinnabar, nickel, cobalt, antimony, platinum, gypsum, sulphur, and other products made a showing that was tremendous in its magnitude.

How great an increase these figures represent over those of a few years ago is seen clearly by a comparison of the output of the mines to-day and that of a few years ago. In 1850 the output of the country was seven and one quarter million tons of coal, less than a million tons of pig iron, thirty six thousand tons of lead, and six hundred and fifty tons of copper.

At the present time nearly one half of the world's supply of steel is contributed by the mines in this country, a quarter of the world's supply of gold comes from the mines in the United States, more than one half of the world's copper and at least one fourth of the world's zinc and lead is supplied from mines here. In the production of zinc the country is second to Germany only, while Australasia and South Africa, by narrow margins, however, exceed this country in the output of gold.

And this condition is all the more marvelous when it is remembered that the mines in this country have all been developed and worked within the last fifty years. It was not until 1860 that the first important silver mine was opened, and this mine began operations only ten years after the opening of the gold fields of California.

In brief this is the story of the growth of the mining industry in this country. The figures tell some of the results of the work of the men who toil in the never ending darkness of the underground world, adding pound by pound, bit by bit, to them.

The life of a miner, surrounded by all the perils that his position is fraught with, is pretty much the same and simple indeed, except in the salt mines, where, as will be explained later, the workers are the aristocrats of the miners' world. They live, the men who work in mines, almost within sight, sometimes actually so, of the mouth of the shaft of the mine where they are employed, with their little families, the male members of which entertain no greater ambition than to follow in their ancestors' footprints and wrest their living from the bowels of the earth. Their houses, as a rule, are dirty and grime streaked from the dust of the mines, for the miner cares little for pleasing effects, and his home—to him—is but a place where meals are served and where he sleeps.

He has little time for his family. In the summer he is up with the first streaks of daylight; in the winter he leaves his bed before dawn, for his work requires his presence in the mine before seven o'clock. Early as he arises, though, his wife is up before him and his breakfast, a hearty one, for these men eat heavily, is ready when he is dressed. Breakfast consists of meat or fish with hot potatoes, and coffee and bread and butter. Dressing consists of slipping on a heavy flannel or woolen shirt, woolen drawers and socks, and woolen or heavy duck trousers. His shoes are heavy and hobnailed and his hat is an affair resembling a small helmet with an oil lamp fixed in front.

The start for the mine is made immediately after breakfast. If the day be cold he wears a short, heavy jacket or reefer.

Shoulders bent and head drooping, his habitual attitude in the mine, the worker sets off with long strides and, without a backward glance, pushes on to the mine.

The shaft through which he enters to his work may be a straight one, sunk perpendicularly into the ground, or a sloping run. In the former case the worker, with his com-

panions, takes his place in a cage or narrow affair like an ele-
vator cage, attached to a cable that runs over a wheel over-
head and is dropped, with a speed scarcely less than that of
a falling stone, to the level upon which he works. In the
case of the sloping shaft he scrambles down afoot or is
lowered in a car that runs upon rails. The visitor, first en-
tering a mine, may well gasp with terror when he is shot
downward through the darkness, and there is good reason
for the prayers and hopes that go up that the engineer at
the levers above is a sober, careful worker. He usually is
and the cage is brought to a sudden stop in exactly the right
position, although sometimes, and these exceptions are not
unknown, the engineer forgets and the cage with its load
of human freight is smashed against the bottom of the shaft,
to be tran formed in an instant into a heap of debris, the
death trap for everyone in it. In the engine rooms of many
mines nowadays, though, there are safety appliances that
automatically stop the machinery when the cage is near the
bottom in case the engineer is derelict.

Once in the mine the work of the miner begins. Some-
times—and these times are looked forward to with no great
pleasure—the worker is assigned to a gang that is putting
in timbers or supports to hold up the walls of the tunnels
and prevent cave-ins. This dead work, as it is called, is, of
all the miner's work, the most exhausting, for some of the tim-
bers used weigh more than five hundred pounds and can only
be placed in position by a block and tackle. But usually
the miner puts in his time at his regular occupation, blasting
his way into the ore that surrounds him, tearing it down with
his pick and shoveling it into cars that are hauled to the sur-
face and sent back to him empty. In this work he may have
an assistant, assigned to him or hired by him, the latter usually
if his work is by the yard—a running yard in advance.

Before beginning work, however, the miner makes his
test for fire damp, for, although tests are made about 2 o'clock
every morning by the fire boss, the deadly gas to which is
traced so many mine horrors may accumulate within a few
hours.

With the air in his gangway pure enough to permit of his working steadily the miner proceeds rapidly. With a small breast drill he drives a hole four or five feet deep into the wall before him. Into this hole he inserts a dynamite cartridge from a number that he carries in a metal case, tamps the cartridge in firmly with fireclay and connects his fuse and lights it. Then, retreating to a safe distance he awaits the explosion that displaces tons of the mineral. When the smoke and fumes clear away he returns to load the cars that are sent to him. Thus, through the day he proceeds. Between six and twelve blasts may be made during the day if cars are sent to him to carry away the ore as fast as he can blast and load the cars, which usually hold about four tons.

A miner's day is less than ten hours as a rule and after his work is over he returns home, where his first move is to take a bath and change all his clothing. Then, after his thorough scrubbing to remove the grime of the mine he has supper and spends the evening smoking his pipe or conversing with companions until the evening wanes and he goes to bed. He generally retires early, for his work demands a strong constitution, and that, as the miner knows, is best obtained and retained by regular hours of rest.

Inventions of recent years have expedited and lightened considerably the work of the miner. Steel drills driven by compressed air, well ventilated shafts, automatic dumping cars and other improvements have made his work lighter and in many mines the position of the underground worker is far better than that of his co-worker the laborer, above ground. Mines as a rule are cooler in summer and warmer in winter than the upper world.

Mining for rock salt and in salt mines has advantages over all the other forms. In the Carpathian mountains, in the salt mines the workers live in underground villages in the great, high-ceilinged vaults in the mines, surrounded by walls that glisten with light refracted by a million crystals of every color in the rainbow and beneath high roofs that rival the sky in beauty. Rock salt is found in varied hues of red, yellow or blue, or, as in the mines of Wieliczka and western New York, grayish white. Its tenacious nature enables

miners to sink shafts through it and hollow out large cham-
bers without the use of any supports or props. Much of the
mining in these salt mines is done with no tools except pick
and shovel, although in nearly all the mines dynamite is used
to loosen great blocks of it. These blocks are afterwards
crushed in great breakers.

In these salt mines children are born in the villages
beneath the surface and have been known in some cases to
grow to the age of ten or fifteen years before they ever saw
the surface of the earth or the mouth of the shaft of the mine
in which they lived. In the seclusion of the subterranean
fairyland the miners and their families lead lives of quiet,
far removed from the battle that surges above them, careless
of the worries of the world, protected from the elements and
adversity, and with a means of livelihood all around them
and always waiting.

There is another side, though, to the miner's life; a side
which all too often forces itself forward, and that is the side
that presents itself when an accident takes place in one of
the mines, in a level probably a thousand feet or more be-
neath the surface of the ground, a thousand feet from the
mouth of the shaft and the upper air. The blast is the thought
that strikes terror to the hearts of the miners when a cry of
alarm rings through the levels, and the same thought strikes
a chill to the hearts of the anxious ones above when news of
an accident in the mine spreads like wildfire about the shaft
to the houses in which the workers' wives and families live,
and brings them wild-eyed with fright, and with prayers on
their lips to the office of the company to learn of the horror
that may deprive them of a father or a brother or a husband.

It is only within the last few years that anything like
sufficient precautions have been taken to safeguard the work-
ers. In the Pennsylvania coal mines, for the first fifty years
of working, the ventilation was always bad and there was but
one shaft worked to every mine. The terrible fire in the
Avondale mines thirty years ago, smothering and burning
one hundred and ten men, compelled laws that demanded
two distinct shafts for every mine—one for entrance and
the other for egress, and specifying the minimum number

of cubic feet of air to be provided for each underground workman. Other laws have been enacted governing the methods of working mines, the manner in which timbering must be done, and setting forth protective measures. All states have enacted such legislation for the protection of the miners.

With all the protection afforded, however, enough catastrophes happen every year in the mines of any state to fill a score of pages with the varied list.

The story of the horror in the Crown Point mine, in the Comstock lode, April 7, 1869, not only illustrates the terrible effect of the slightest carelessness in a mine, but also pictures the most dreaded happening in a mine—an outbreak of fire.

Previous to the fire of the 7th of April there had been two serious fires in the Comstock lode but both had been extinguished without loss of life. The third fire started in the morning in the eight hundred foot level of the Yellow Jacket mine, next to the Crown Point. To this day its origin is somewhat of a mystery but the investigators have declared that it probably was kindled by a careless miner who left a torch leaning against a wooden support in one of the passageways of the level. For some time the flames crept along the drift unnoticed, as no one happened to be working there, until finally, with a deafening crash the charred timbers fell beneath the weight of the roof, driving blasts of foul air and smoke into the drifts of the Crown Point mine and scattering fire through the adjoining drifts of both mines.

It was the hour for the changing of the shifts—the night and the day—and to this fact many owed their lives. John Murphy, in charge of the station at the eight hundred foot level of the Yellow Jacket, felt the sudden rush of wind that followed the collapse and then the lights in the station went out, leaving him in darkness. The foul air choked him, he crouched close to the floor, his head enveloped in his rubber coat to escape the fumes, he heard a faint voice from below calling "Murphy, for God's sake send us a cage, we are dying," and then he lost consciousness. He was rescued in time and recovered.

All the workmen near Murphy were struck down and killed by the blast, but in the adjoining mine—the Crown

Point—the effect of the blast was worse.   The cage was descending into the Crown Point mine when the rush of foul air that followed the collapse of the drift came and at the seven hundred foot level the descending cage struck the current.   The men dropped to the floor of the cage in agony as they breathed the rank fumes but the speed of the car continued until it reached the eight hundred foot level, where it stopped.   There, amid a stifling smoke, the workers who had escaped the blast were crying and when the cage appeared there was a mad rush for it.   Loaded to its utmost capacity with others fighting for a chance to get on, it was shot upwards.   Without delay it was lowered again and another load was brought up, many of these all but dead from the fumes below.

In the meantime the alarm had spread around the mouth of the shaft, fire engines began to arrive from Virginia City, steam whistles screeched, and the families of the workers came hurrying from all sides.

Every possible effort was put forth to aid the men imprisoned beneath the surface and at noon a piece of pasteboard, bearing the following words, and a lantern, lighted, were attached to the bar of the cage and lowered into the shaft of the Crown Point:

"We are fast subduing the fire.   It is death to attempt to come up from where you are (the 1,000 foot level).   We shall get you out soon.   The gas in the shaft is deadly. Write a word to us, and send it up on the cage and let us know where you are."

The cage was held at the one thousand foot level to give anyone who might see the pasteboard and the lighted lantern time to read and answer the message.   Then, after the interval of anxious waiting the cage was drawn back to the surface.   There was no answer to the message.   Then the roll of three mines was called and it was found that thirty four miners were dead or missing.

In spite of the knowledge that some of the miners might be alive in the levels it was not until after midnight, following the morning of the fire, that four of the most reckless of the rescuers at work around the shaft, took a desperate chance

and descended to the one thousand foot level of the Crown Point mine where they came upon many dead miners, suffocated by the dreadful fumes. One by one the bodies were lifted to the surface as they were found and there identified by the stricken families. The funeral of these men was the most solemn and largest ever seen on the eastern slope of the Sierra Nevada range.

While the rescuers were at work preparations were being made to flood the mine as soon as it was found that all the imprisoned men had been rescued. Streams of water that were turned into the mines boiled when it came into contact with the heated walls of rock and the burning timbers. Fresh air was pumped into the mines constantly to supply oxygen to the fighters and to any imprisoned men, but the oxygen fed the fire at the same time and made the efforts of the fire fighters useless. Finally, April 12, when the last hope of rescue had been abandoned the openings to the mines were closed and steam from the boilers in the engine room was forced into the drifts and passageways for seventy two hours. Then when the main shaft was re-opened the fire broke out afresh and it was not until the mine was closed again for forty eight hours and live steam turned in again, that the fire was extinguished and the mine made tenantable. Three days after the re-opening of the mine repair gangs were at work and a few months afterwards, with all the charred timbers and evidences of the fire removed the mine was working full blast, sending its usual output of ore to the surface.

The risk, however, of working in mines is decreasing yearly, and every new scheme or device that aids the mine owner to make more certain the safety of the men at work for him below the ground is adopted without hesitation or regard to the expense.

In the early years of mining in this country old fashioned methods that prevailed in the old world were taken as models and the results were always unsatisfactory and very often entirely negative. The first notable showing of enterprise came when the great rush began to the Pacific coast after the discovery of the gold mines there. At first the ordinary course of mining in opening ore mines was followed, but

the necessity for overcoming great obstacles formed by nature acted as a stimulus that stirred these pioneers to still greater feats.

The development of the Comstock lode was marked by tremendous feats of engineering skill and daring. Before that day miners were wont to prop up the drifts through the narrow veins with a timbering of tree trunks or by posts surmounted by a cap piece. In these gold mines of California, however, every foot of space was precious, every carload of ore was worth refining.

The problem was solved finally by Philip Deidesheimer, a mining expert working as a superintendent in one of the mines, who introduced the method of square set timbering— filling every space with blocks piled beside each other and one upon the other. These blocks were put in one at a time as fast as the ore was taken out. One chamber, filled in this manner, was more than six hundred feet long, five hundred feet high, and two hundred feet wide.

Thousands of men found employment in this and other mines, in this region, striving and bustling villages and towns like Virginia City and Gold Hill sprang up and prospered. There was a dearth of water in these towns and the nearest supply of good water was a lake high up among the mountains. From the lake to the valley of the Carson river there was a fall of a mile and the mining towns lay a thousand feet above the valley on the other side from the lake.

"It's impossible," was the brief statement of the first engineer that was called in by the mining kings Mackay and Flood, who owned the greater part of the mining land in that part of the country.

"It's got to be done," they replied to the shrinking engineer, fearing to trust himself with work of such magnitude. And done it was. It was necessary, in order that the mines be worked, that water be got to the two mining towns. And water was brought to them over the valley a mile deep. Other obstacles were met and surmounted in much the same manner. There was no hesitancy in those days, no counting the danger; the only thing that was counted was the profit and loss, and when there seemed an opportunity for a feat of daring and

skill that would bring the balance in the former column higher it was done.

Hand drills became too slow for these men and machine drills superseded them; glycerine compounds took the place of the old cartridges of black powder for blasting and work was pushed as fast as human energy could go.

Shafts were sunk everywhere that gave promise of return. Mining of drifts and cross cuts through the lode and the stopping of the breasts of ore were pushed at a rate exceeded by that set in any other mines in the world. Finally, as the shafts were sunk downward the inrush of water became too great for the pumping engines and the mines began to flood on the Comstock lode. Pumping engines that made the Comstock mine the wonder of the country because of the size of the engines were installed, but it was of no use and fear was entertained in many sources that the work would have to be abandoned.

Then, in this supreme moment came Adolph Sutro, with a plan for a tunnel and the nerve to believe in his plan. The tunnel was to be four miles long and was to drain the lode. It was begun all right, but for lack of backing did not reach the mines until the shafts were a thousand feet below the end of his tunnel which entered the lode sixteen hundred feet below the surface of the ground.

But all the time that work was being pushed on the tunnel the mines were never idle. Despite the water, and, what was far worse, the terrible heat, men worked at the level of the tunnel and below all the year around. The lode was in a basin of geysers and the men, summer and winter, worked stripped to the skin, wearing nothing but a loin cloth and slippers.

Many times the temperature in the drifts at these levels registered a hundred and thirty degrees, which, at that level, with the foul air made it almost impossible to live, to speak not at all of working. The ends of the air pipes, through which the mighty engines drove fresh air down to the workers, were set only twenty feet behind the men at the faces of the ore in the drifts, but even with this it was impossible for a man to remain at work more than four minutes in the hour.

When his time was up he would stagger away and bathe his head in a stream of water from a water pipe. In these hot drifts more than thirty men were smothered by the foul air and the heat in one year and thirteen more were scalded by falling into the sumps, the seething pools at the bottom of the shafts. With the air blower turned off the temperature in those drifts rose twenty and even thirty degrees and at one point where a thermometer hung against the rocky side of the drift the mercury in the tube registered one hundred and sixty five degrees Fahrenheit, which at that level—many thousand feet below the surface of the ground but yet far above the level of the sea—is but twenty five degrees below the boiling point of water.

Yet, undismayed the miners worked against all these disadvantages until, twenty years after the opening of the Comstock mines one of the shafts had been sunk to the depth of more than half a mile into the earth, notwithstanding the terrific heat, and others were under way designed to reach the lode at a depth of a mile.

John Mackay, part owner of the mine, voiced the sentiment of everyone connected with the work when he said:

"If there is silver enough in there to pay for the cost of taking it out and then leave something over for us I will see that it is got out. There must be some way and I will find that way."

He knew every foot of every one of his mines. He was vigilant always, watchful ever for accidents, carelessness on the part of his men or for ways in which the lives and safety of his employees could be safeguarded. He demanded that they take chances, but there never was a chance that he asked others to take that he would not, and did not take himself. He was cool and cheery, and always harassed by the fear of a fire. He had seen the fire in the Crown Point mine a few years before the opening of his Comstock properties and he never forgot the horrible tragedy that followed the carelessness on the part of one of the men.

The risks that Mackay encountered and the chances that were taken in his mine surpassed those taken in any other mine on earth, but the compensation was abundant.

Three hundred and fifty million dollars worth of bullion was taken from the lode. The development of mining in this lode made necessary the invention and adoption of the best mining machinery in the world and trained a magnificent body of American miners who set a pace that spurred up prospecting and mine development all through the United States and Canada and even in the old world.

One of the methods introduced in the Comstock mines had much to do with the rapid development of other mines of different ores. That method was the square set timbering scheme that made easy the opening of the great copper lodes of Butte. Soft and shifting vein formations that warped massive timbering and crushed shafts lost their terror for miners when the men saw the ease with which the Comstock miners contended with such and still greater difficulties. In the mines of Colorado when they were first opened the inrush of water was so great that often it was necessary to pump forty tons of water out of the mine for every ton of ore extracted. In the Ontario and Friedensville mines the flood was greater but the massive pumps of the Comstock mines were able to cope, partly, and with some degree of success, with the worst floods that the lode ever saw. The sinking of shafts to great depths became comparatively a simple problem after the engineers and workers in the Comstock mines had shown the way. In Bohemia it took generations of miners to sink a shaft to the depth of thirty-two hundred feet. The two Tamarack shafts in the Michigan copper field were driven to the lowest depths entered by man —4,218 and 4,143 feet beneath the surface.

It was not until the South African diamond mines were developed by an American manager, Gardner Williams, that the progress of American mines was equalled outside of this continent.

Of course work may not be done so rapidly in some mines as in others, sometimes on account of the difference in the kind of ore and again because of a difference in the formation of the veins in the two mines.

Coal, salt and stratified deposits are found in layers, sometimes perfectly horizontal, as originally deposited, again

lying at an angle and often broken by faults. It is necessary to follow the dip or angle of inclination of the bed in mining for such deposits. This is determined by tracing down the outcropping of the vein, if there be one, by cutting a passage-way or incline that follows the slope of descent, or by sinking a vertical shaft and running horizontal passageways—drifting as it is called—to the lode or vein. Deposits in high hills are reached by driving a tunnel into the hillside.

After determining the dip of the vein approximately a working shaft is sunk, at the angle taken by the vein, or vertically, and from this shaft, at different levels, horizontal drifts are cut, drilled or blasted through the deposit. Through these horizontal passageways the ore is drawn to the shaft through which it is hoisted in cars to the surface of the ground.

There are many methods of extracting the ore but they vary with the formation of the veins and seams of ore, and with the nature of the deposit. One plan is extraction of the ore by slicing it off from the top in successive layers, but the usual plan followed is to drill and blast from a working level to the next level below.

In coal mines the passages entering the seams at the working levels from the shafts are called gangways. They may run in any direction towards the seam, around it or through it and from these gangways other passageways are driven off breasts in which the miners work cutting into the seam. In coal mines where the deposit is hard anthracite, the gangways are often ten and twelve feet wide and from twelve to twenty five feet high, while the breasts are from twenty to thirty feet wide and separated by intervening walls or pillars from fifteen to seventeen feet thick. The breasts and gangways are supported by heavy timbers, surmounted by cap pieces and cross pieces and set at intervals varying with the nature of the deposit.

In ore mines the drift or passages are run along the length of the vein and often when the vein is narrow a single drift is sufficient to enable workers to exhaust it. When the vein is wide, parallel drifts, intersected by cross cuts, are made ranging from four and a half to five by seven feet, within the buttresses used to support the roof and walls of the gang-

way. When large masses of ore are to be removed, the square set timbering explained heretofore is resorted to as the best plan.

Only an expert can tell however the direction taken by veins and the best manner of mining for them. Although the various ores are becoming well known, the majority of people have only a very indistinct idea of what a metal bearing vein looks like. There is no glittering show in a gold mine for example. The black sulpharet ore on the top of the great Comstock lode was handled for months before anyone suspected its value. The same is true of the carbonates of Leadville. No mercury drips from red cinnabar like water from a wet sponge. The novice will fail to see lead or zinc in the dull gray rock that contains those ores, and he will not pick up as copper bearing a rock sprinkled with green and blue specks. Even the richest diamond fields in the world are but areas of blue ground to the eye.

It requires skill and a high degree of training to find a mine, but it requires all this and courage of the highest type to drag from the earth its treasures—the kind of courage that was exemplified in the early history of mining in the country; the same kind of courage that animates the great underground army that is working away, fighting odds and overcoming obstacles in the mines of America at the present day. It is an army that is growing every year and with its growth its victories—measured by the increased outputs of the mines —are becoming greater.

UTILITIES FOR HANDLING RAW MATERIAL.

BY WALDON FAWCETT.

[Waldon Fawcett, author; born Salem, Ohio, February 23, 1875; is one of the most popular contributors to newspapers and periodicals on technical matters, writing for the most part as the result of personal investigations; in this connection he has traveled through the United States and Europe collecting information; also syndicates weekly articles on industrial topics to a large syndicate of newspapers. Author of several works on economic and industrial subjects. The article here published is used by arrangement with the Century Magazine.]

The existence in crude form of some elementary devices for hoisting or otherwise handling certain classes of raw material, notably stone and logs, dates back many years, but it has been within the past decade and a half that there has taken place that remarkable progression which has constituted one of the most impressive achievements of the modern engineering world. Not only is bulk material, practically without limitation as to weight, hoisted to any height desired, but it has been rendered possible to transfer commodities at high speed for either long or short distances, and thus the mechanical operatives of the modern industrial world secure the trilogy of an economy of time, a saving of labor and the conservation of expenditures.

Easily the most interesting as well as the most significant advancement in this broad field is found in the introduction of improved methods for the handling of those two most important commodities—coal and iron, the latter embracing of course a variety of forms from iron ore to finished steel. Indeed, in the case of the most useful of metals there has been evolved a cordon of mechanical devices, the functions of which so supplement each other that from the time the ore leaves the mine until it has been transformed into marketable iron or steel the factor of manual labor directly applied, is practically eliminated.

The initiatory machine in this chain is found in the steam shovel which takes the iron ore from the open pit mines of the Lake Superior district and later is called into requisition

to transfer the ore from the stock piles at the mines to the railroad cars provided to carry it either direct to the blast furnaces or to the vessels wherein it will be given water carriage to the great lakes. The steam shovels for the latest approved practice range in weight from fifty five to ninety five tons, and in this feature alone is afforded ample evidence of progress, for but a few years since the shovels of thirty five or forty five tons weight were deemed sufficient for all the exactions imposed by this work. The shovels now in use have dippers ranging in capacity from two and one half to five yards, and something of the celerity of movement with which they are operated may be appreciated from the fact that on many occasions ordinary railroad cars are loaded with ore and pushed out of the way of the machine at the rate of one every two minutes.

In the unloading of the immense cargo carrying vessels of the inland seas, wherein the iron ore is conveyed from the Lake Superior mining district to the ports adjacent to the blast furnaces of the middle west, are employed the various forms of hoisting and conveying apparatus, all of American origin, which probably constitute the most famous of all the installations for transportation purposes. In this field of activity methods advanced, at a single step, from the old plan of unloading the vessels by means of wheelbarrows and permanent trestles to the bridge tramway structures which are up to the present date in almost universal use.

The conspicuous elements in any such installation embrace the elevated tramway—spanning the dumping ground or railroad yard and connecting it with the vessels—the trolley or carriage traversing this tramway and the system of mechanism by which the whole is operated and controlled. Such an apparatus is operated, of course, by a motive power located beyond the limit of travel, and while the operation is at every stage subject to the control of an operator, a large proportion of the important functions are automatic, the positive movements of the parts through such operations being derived entirely from the bodily movement of the apparatus itself, while actuated by momentum, gravity or the direct action of the hoist rope. Attached to the trolley of

each machine is an automatic dumping tub or bucket, the discharge of which may be made at the will of the operator, either at the full height of the tramway or by an automatic deflection of their motion and with no appreciable loss of speed the buckets may be caused to descend and discharge their contents at any point below the tramway.

The bridge tramways are usually built in plants or groups of three or four bridges which may be supported on either single or double piers. The tramways are, as a rule, provided with hinged aprons designed to extend over the vessels and very frequently cantilever extensions are provided at the opposite end, so that the buckets are enabled to serve a space of 300 to 350 feet in width. The operation of the tub or bucket is effected by means of a wire cable connected with a drum in the engine room, and the engine is usually of the double cylinder type. The piers supporting a bridge tramway are on wheels, and it is thus possible to skew or move sideways the entire structure, in order to bring the bridges in line with the hatches of the vessel being unloaded. This type of machine hoists the bucket of ore from the hold of the vessel, conveys it to any desirable point on the tramway and automatically dumps the material on the dock or into waiting railroad cars.

As indicating the capacity of the bridge tramway, it may be cited that a plant of three bridges will readily handle 1,200 tons of ore in a day of ten working hours, hoisting the material, conveying it a distance of 100 to 150 feet, and dumping automatically. In the case of the bridges of exceptional length a round trip can be made from the hold of the vessel to the extreme end of the cantilever and back again, a distance of 600 feet in one minute, and in actual operation a rate of 45 seconds per trip has been maintained for hours at a time. The buckets or tubs for conveying ore are usually of one ton or a ton and a half capacity. There are several modifications of the bridge tramway system, notably cable tramways in which wire cables are substituted for the bridges and what are technically known as fast plants wherein instead of the long bridges there are extremely short ones with tramway projections over the vessel and cantilever exten-

sions over the railroad tracks on the dock, the effect of this short haul being to reduce tremendously the lapse of time necessary for the transference of raw material from vessels to cars.

In the case of all forms of bridge tramway apparatus it is necessary to employ large gangs of men to fill by means of hand shovels the tubs or buckets carried by the trolleys, and naturally therefore there is in the transportation world a tendency to regard with favor the latest inventions in the line of machinery for the rapid unloading of iron ore, namely, the automatic unloaders which dispense entirely with human energy directly applied in the unloading operations. The fundamental principle of all the automatic unloaders is found in the operation of some sort of a clam shell bucket which is let down into the hold of a vessel with its iron jaws extended and, closing them, retains in its grasp one or more tons of ore while it is lifted from the hold and run back to a stock pile or waiting railroad cars after the manner of the bucket of the bridge tramway. The original automatic unloader, introduced only a few years ago and in active use to-day, weighs several hundred tons, and is equipped with a great mast to be lowered through the vessel hatch and from which depends a clam shell bucket capable of holding ten tons of ore. The later patterns of unloaders, automatic in their action, are fitted with excavating buckets of only about one ton capacity, and which therefore permit of hoisting and transference by wire cable instead of necessitating the ponderous iron and steel structure required to support the mast and clam shell in the original design.

Bridge tramways similar to those in use on the ore unloading docks are employed in the furnace yards to convey the ore from the railroad cars to stock piles, and a patent furnace hoist automatically conveys the ore together with the coke and limestone to the top of the blast furnace and performs the operation of charging. The automatic hoist consists of an inclined iron trussed bridge reaching from the floor of the stock house to the top of the furnace shell and from thence over the top opening of the furnace. On this bridge is laid a track of T rails on which travels a skip or car,

containing the charge of one to three tons as may be desired.
The track is so arranged at the top that the contents of the
car are automatically dumped into the hopper on the arrival
of the car at the top.   The skip car is hoisted or hauled to the
top by a double engine with a friction clutch drum.

The exigencies of handling great quantities of coal for
shipment have been quite as productive of ingenious mechan-
ical devices as have the requirements of the iron industry.
Bridge tramways have been employed extensively for both
loading and unloading fuel, and in the case of anthracite coal
clam shell buckets and bucket shovels which scoop up the
coal have been introduced in connection with the bridge
tramway instead of the ordinary bucket.   However, pre-
eminent among all the varied forms of coal handling appa-
ratus stands the car dumper, a class of machine, each step
in the evolution of which has been marked by a distinct type
of apparatus, but which has finally reached a point of de-
velopment where it is possible for one of these machines to
hoist a loaded coal car into position alongside a vessel, pour
its contents into chutes communicating with the hold and
return the empty car to the track in the elapsed time of one
minute.   In the case of the most approved styles of car
dumpers the loaded car is clamped to the track in a sort of
cradle in such manner that it may be turned completely over
and yet by means of a reciprocating movement on the part
of a huge pan suspended in the framework of the machine and
connected with the chute leading to the hold of the vessel,
the coal is transferred with a minimum amount of breakage.

A class of coal handling machinery in which recent years
has witnessed great development is found in the various forms
of chain elevators and link belt machinery.   This form of
equipment is used extensively at railroad coaling stations
designed to supply fuel to locomotives.   In a representative
installation one run of the upper conveyor is for stocking the
coal and the other for distributing it into chutes, while the
lower conveyor delivers coal from storage.   Each conveyor
is an endless chain interspersed with metal partitions forming
pockets, is 600 feet in length and has a capacity of 120 tons
of coal per hour.   In many stations an inclined conveyor de-

livers coal from cars to a distributing conveyor and the latter apportions the fuel among twelve or more chutes. Conveyors of this same general type are also used for transferring coal from mine to storage pile or cars. For such utilization there is selected apparatus of great simplicity of design, namely, a scraper conveyor with steel flights of proper shape attached to the chain and drawing the material along in a steel trough. Some installations of this character have a length of about 300 feet and a capacity of four tons of coal per minute.

Modifications of the belt conveyor are now to be found in use in almost every branch of the industrial domain, being put to a variety of uses ranging all the way from the movement of grain to the carriage of logs and stone. Moving platforms, constructed on the endless chain plan, also have an important place among the utilities for handling bulk commodities. Likewise is there extensive employment of traveling cableways and aerial ropeways wherein either the impetus of gravity or hauling ropes are depended upon for propulsive power. Some of the recently installed traveling cableways have a span exceeding 700 feet and are adapted for handling loads of from five to ten tons. The most modern of all of these aerial transportation systems is that designated telpherage, whereby electricity is relied upon as an operative force. In this class of installations the overhead trolley system of the ordinary electric railway has simply been adapted to the rope railways, and by the provision of an ingenious device the electric car or telpher is enabled automatically to slacken speed when approaching a curve, resuming the normal rate of travel when the dangerous point has been passed.

The part which cranes of various kinds have played in the solution of the problem of the economical handling of raw material of various kinds is indeed an important one, and there has been a steady increase in capabilities until there are now in service in the United States a number of cranes each of which is capable of handling a load of one hundred tons.

Easily the most remarkable of all the cranes yet constructed are the great balanced cantilevers invented by Alex-

ander Brown, an American. The cantilever crane is applicable to a large range of work and is the most perfect machine yet devised for use in handling armor plate and other heavy parts in shipyards and manufacturing establishments generally. The cantilever is divided into two arms, which in some instances have a span of over 350 feet. By means of trolley and hoist block, mounted on the cantilever of the crane, the load can be hoisted from the ground and traversed from one end of the cantilever to the other, the pier or base of the crane being so arranged that the load passes through it. These cantilever cranes have an automatic counterweight running on a track along the bridge and above the hoisting trolley, and connected by ropes to the latter, so that whatever the position of the hoisting trolley on one arm of the crane, the counterweight at all times automatically occupies a similar position on the other arm. The latitude of the operations of the apparatus is further broadened by reason of the fact that the entire crane travels by its own power up and down the track or trestle on which it is mounted. A crane of this type is capable of marvelous speed. A load of fourteen tons may be hoisted at a speed of 200 feet a minute; the trolley travels back and forth along the cantilever arms at a speed of 600 feet a minute; and the entire crane has sufficient propulsive power to enable a speed of 750 feet a minute in traversing the track or trestle.

In conclusion attention must be given to the so-called lifting magnet, the most wonderful of all the new appliances for handling weighty raw material. The electromagnet, by the aid of electricity, performs on a large scale something of the same function as the toy with which children have long been familiar. One magnet will elevate a mass of metal weighing two tons and it is possible to use several magnets simultaneously in handling a particularly heavy steel plate or bar. This plan of handling material also possesses immense economic advantages, inasmuch as a single mechanic is usually in charge of the crane to which the magnets are attached.

ELECTRICITY IN MINING.

BY THOMAS COMMERFORD MARTIN.

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The mining industry to-day constitutes one of the most important fields for the application of electric current. There is hardly a country in the world and hardly any department of mining in which electrical appliances are not employed, and in many instances the installation and equipment are of a most extensive character. The whole tendency of the time is to develop mining industries along electrical lines, and in fact to employ electricity continuously from the very first contact with the ore to the stage at which the finished product is ready for the market. It is proposed, to limit the present treatment of the subject to electric mining, as both electro-metallurgy and electrochemistry are distinct fields of technical work, dealing with manufactured material rather than with the cruder and more primitive processes of winning the minerals from the soil.

In the United States, as elsewhere, the introduction of electrical mining apparatus has been greatly stimulated of late years by the high degree of perfection attained in the art of power transmission. A great many mines and mining camps in regions where fuel was either very costly or difficult to obtain have been brought within the range of profitable working through the utilization of some distant water power. The single and polyphase alternating current, with its flexibility and high range of pressure, has made it possible to transmit power from water courses across valleys and over mountain ranges for scores of miles, so that to-day large areas, which but for the assistance of electricity would have remained neglected, because unavailable, are being worked.

The profitableness of American mines and the sources of national wealth have thus been enormously increased.

The number of mines in the United States reporting electric power in 1902 was 802, with a total of 154,050 horsepower. By far the larger proportion of these—namely, 688, with a total of 130,494 horsepower—operated their own plants. There were 131 mines, with a total of 23,556 horsepower, which rented power, but of these mines 17 owned power also. It will be gathered from these figures that the 130,494 horsepower, even if it represents the total current generating capacity, shows a considerable application of electric power; but it should probably be doubled in order to ascertain the capacity of motors installed and using such current. It is a fact well known in electrical plants that motor capacity far beyond the actual current capacity of the generating plant can be installed, for the reason that the consumption of current is variable and intermittent, it being highly improbable that all the consuming apparatus will take full current from the lines at the same time. It is assumable that in a great many instances these plants furnish also considerable current for lighting purposes. With regard to the rented power, it is probable that it is employed almost altogether to drive motors, a very small proportion of it representing electric lighting. Mines in which the operations are so small as not to necessitate the installation of a separate plant are, it is assumed, operated largely by single shifts or during daylight hours; so that while some lighting would be needed, the consumption of current would be quite small in proportion to the consumption for hoists, pumps, and other motor driven mechanism.

Four fifths of the electric power reported was concentrated in three industries—coal mining, cement working, and the gold and silver industry. By far the largest item is that of bituminous coal mining, such mines, numbering 309, reporting electric power with a total of 68,139 horsepower; and these figures must be supplemented by those for anthracite coal mining, with 17 plants, reporting 5,755 horsepower. It will be seen that those two groups alone represent nearly one half of the total horsepower.

Electric current for mining purposes is usually obtained in one of two ways, depending somewhat upon the nature of the mine in the first place, and secondly upon the environment. In coal mining regions it is natural that each mine should draw upon its own fuel resources for power, the plant being stationed at the pit mouth; but even in such cases, where there is a group of mines it is sometimes found convenient to concentrate the power generating apparatus, transmitting the current to a distance. This has been done in an even more comprehensive way in western mining fields, one steam plant which utilizes coal delivering its energy to mines no less than 26 miles distant, in districts where water power is not available. Where the generating plant is at the mouth of the mine it is customary to employ apparatus producing low tension direct current; but where longer distances are involved the alternating current has been resorted to, in the same manner as in central electric lighting and railway plants. The current is generated at high potential by polyphase dynamos and transmitted to substations, where it is lowered in pressure and converted into direct current for use.

One of the first plants of this kind for a mine haulage system was installed at Ehrenfeld, Pa. The haulage in this mine was accomplished by rope driving and mules until the main heading, which should eventually extend 5 miles underground, was nearly 2 miles long. This method was then replaced by an electric system embodying the generation of a 3-phase, 25-cycle, 5,600-volt alternating current near the pit mouth. This current is transmitted by insulated cables to a substation in the mine itself, near the center of the actual operations and about 9,000 feet from the power house. Through the intervention of static transformers and a rotary converter, direct current at 275 volts is then delivered to the haulage circuits.

An interesting variation of this plan is that embodied in the plant constructed for the Raton Coal and Coke company, at Blossburg, N. Mex. When built, in 1897, the coke plant included some seventy five 3-foot ovens, in double banks. In the center was erected a large battery of boilers, to which the waste gases from the coal are conducted through central flues; the gas thus made available is employed to drive gas engines

and dynamos furnishing power for the hauling plant both inside and outside of the mine.   About a mile and a half from the coke ovens is situated the washing and crushing plant, with a capacity of 800 tons in ten hours.   All the machinery from tipple to mine opening is driven by electric motors, a trolley line with electric locomotives bringing the pit cars from the main entry to the tipple.   This idea of the utilization of waste gas in coke fields and blast furnaces has of late occupied considerable thought and attention on the part of mechanical and mining engineers, and important developments are resulting from the employment of electricity as a means of lessening waste.

In most mining districts, however, the work is intermittent, machinery is widely scattered in places difficult of access, fuel is expensive, and the economical use of steam is not possible.   Compressed air, as a means of transmitting power, is handicapped by loss in the compressor and the piping, and is limited to short distances and to the operation of apparatus requiring power regardless of cost.

Under the modern conditions of power transmission from waterfalls, etc., electricity has shown itself to be largely independent of distances, so that, as was pointed out by Mr. F. O. Blackwell, before the American Institute of Mining Engineers, in February, 1903, a given amount of power can be delivered either 528 feet away, at 100 volts, or 50 miles away at 50,000 volts, with the same total amount of copper per horsepower and exactly the same loss of power in the transmission circuit.   With proper choice of potential and system, this loss need not exceed 10 per cent, even when the current is carried as far as 150 miles.

So much has been done in the matter of power transmission for mining purposes that it is difficult to pick out any specific case as thoroughly typical.   But it would be hard to find an instance more notable than that of the Standard and Bay Counties Power companies, in California.   These, consolidating other systems, have a remarkable network of circuits of which one of the largest begins at Colgate, in the foothills of the Sierras, on the North Yuba river, a second at Folsom City, a third at Electra, and a fourth at De Sabla.   From

Colgate to Oakland, where the Bay Counties company's line ends, is a distance of 152 miles; from Oakland to San Francisco, by the Standard company's line, is 70 miles. The tying in at Oakland thus gives a transmission circuit of 232 miles from the latest plant at De Sabla, beyond Colgate, around San Francisco bay and through San Jose to San Francisco. Over the network thus represented, which embraces no fewer than 16 counties, within whose borders lie one half of the population and three fourths of the total assessed valuation of property of the state, several thousand horsepower is delivered daily. Alternating current is distributed to substations at pressures of 40,000 to 60,000 volts and there manipulated and rectified for delivery to establishments engaged in a variety of industries, including a large number of mining plants.

Electric coal cutters constitute one of the largest classes of mining machinery employing electric current. The considerable increase during recent years in the proportion of machine mining as compared with that of pick mining is doubtless due to the adoption of these machines.

The older form of machine is of the pick or puncher type run by compressed air, but of late years the chain form driven by electricity has rapidly come into use. Some interesting details with regard to the introduction and utilization of electric coal cutting machinery were recently made public by Mr. S. B. Belden, who is connected with one of the largest concerns manufacturing such apparatus. Speaking of the first chain machines, designed by Mr. J. H. Jeffrey, Mr. Belden stated that their height precluded the possibility of operating them in thin coal, and that for several years no attempt was made to build a machine designed specially for such work. Even when the chain machine was an established success, it was a question whether a machine weighing more than a ton could be employed in coal ranging between 32 and 36 inches in thickness. But after these large machines had proved successful in thick veins they began to be used in lower coal until the minimum thickness of the vein had been reached.

Gradual evolution has produced a smaller and lighter machine, so that there is now in use one which has a height of only 18 inches, or, with the moving truck, of 28 inches, and a

weight of only about 2,500 pounds. As this machine rests upon a wide flat shoe board it can easily be moved along the face of the coal by the operator and his helper. A brief description of the apparatus will be of interest. On an outside frame, consisting of two steel channel bars and two angle irons riveted to steel cross ties, rests a sliding frame consisting of a heavy channel or center rail, to which is bolted the cutter head. The cutter head is made entirely of two milled steel plates, which bolt together, forming the front guide for the cutter chain. This chain, which is made of solid cast steel links connected by drop forge straps, is carried around idlers or sprockets placed at each end of the cutter head and along the chain guides at the side to the rear of the machine, where it engages with and receives its power from a third sprocket, under the motor. The electric motor, which is of ironclad multipolar type, rests upon a steel carriage, which forms the bearing for the main shaft. The thin vein machine is equipped with a self propelling truck, the motor which operates the machine being also geared to the truck axles. A reversing switch is provided, so that the truck can travel in either direction, and when the machine has reached its stopping point, either forward or backward, it is checked by an automatic cut off. The return travel is made in about one fourth of the time required to make the cut. Where the grades are heavy the truck is of advantage, and where the room lies to the dip it obviates the necessity of brushing down the roof for the entry of mules.

It is stated by Mr. Belden that many mines having only 28 to 30 inches of coal are being operated entirely with thin vein machines, and that a fair average for such machines is the cutting of at least 50 tons of coal per eight hour shift.

According to the schedule adopted in No. 8 vein of Ohio coal, the cost of pick mining in rooms is 90 cents per ton, while the cost of machine mining in rooms is 11 cents, with $52\frac{1}{2}$ cents for loading after machines in rooms. This shows a saving through the substitution of machine mining for pick mining of $26\frac{1}{2}$ cents per ton. A liberal allowance for operation and depreciation would leave a net saving of over 13 cents per ton, and the four machines should produce at least 75,000

tons per year. Numerous data received from various mining sections bearing upon the cost of operating such apparatus per ton of coal give figures ranging from one tenth of 1 cent up to 2 cents, according to the hardness of the coal and the degree of care and skill observed in operating.

Discussing the subject in an admirable article on coal-cutting machinery, Mr. E. W. Parker expressed the opinion that the evolution of the chain machine was one of the most notable steps—and practically the final step—in the development of a successful mining machine. The speed with which the chain machine can do its work seems incredible. After the machine has been placed in position an average period of only five minutes is required to make a cut 44 inches wide, $4\frac{1}{2}$ or 5 inches high, and 6 feet deep, and then withdraw the cutting frame. In fact, for one of these machines there is claimed a record of cutting 1,700 square feet in nine and one half hours.

As to the advantages of the modern chain machine over the earlier forms of pick machine, the former bases its claims upon the rapidity with which the work is done, the very small amount of slack coal that is made in the cutting process, and the fact that the runner is not subjected to the wearisome racking of the pick machine. The advantages of the pick machine, which is driven by compressed air, and strikes about 190 to 210 blows per minute, are, first, that it can be used in mines where the narrow conditions of room and floor do not permit the introduction of chain breast machines; and, second, that in mines where the quantity of gas is so great that safety lamps have to be employed it obviates the dangers which might arise from sparking if a motor driven machine were employed.

Several long wall machines—driven sometimes by compressed air, but frequently by electric motors—are in use. As the name indicates, in long wall mining the coal is extracted from a long face, which is gradually moved forward in widening, irregular circles. The nature of long wall work is such that the face must be jagged or circular instead of straight and regular, as in room and pillar mining. One of the leading types of long wall machines, involving to a cer-

tain extent the principle of the chain breast machine, consists of an endless chain operated along a narrow frame or arm extending from the side of the machine and so adjusted that it can be operated at any angle up to a right angle. A change in the angle of the cutting frame will increase or diminish the thrust on the track; in the same way the machine can be made to follow any irregularity of the face of the coal. The cutting frame can be extended over the right or left side, so that as the machine moves the cutting can be accomplished in both directions along the coal face. The height of the machine is only 18 inches, and its weight is only about 3,000 pounds, so that it can be operated in very thin veins. It has a wide range of cutting speed, and can be made to undercut to any practical depth. In going through narrow places and also in moving or changing the cutting bits, the cutting frame can be swung out behind the machine instead of from the side. Like the ordinary chain machine it is operated by two men, and is said to be as available for room and pillar work as for long wall mining.

Shearing machines constitute another class of apparatus of this nature. They are built on the general plan of the chain undercutting machine. The cutter frame is located in a position normal to that of the undercutting, the shaft in the armature of the motor being parallel to the center rail.

The application of electric drills to mining work has been the subject of considerable study and experimentation for many years past, but not until recently have these drills been successful. Drilling is one of the few classes of operation in which a reciprocating motion is preferable if not necessary. The air drill has a reciprocating motion; the electric drill, on the other hand, necessarily has a rotary motion, the effort to develop electric power practically by reciprocating motion having been abandoned at a very early stage in the development of the electric motor. Moreover, the air drill has shown itself very hardy and capable of withstanding unlimited rough usage; whereas the electric drill has usually proved to be a delicate and sensitive piece of mechanism, easily deranged and expensive to repair. On the other hand, the degree of efficiency of the air drill is relatively low, the electric motor

being able apparently to do the same work with a consumption of about one tenth of the power. Moreover, the electric drill does not sustain the further loss in efficiency to which an air compressing plant is subject at a high altitude, nor is it affected by a low temperature, which in an air compressing plant freezes up the exhaust.

A report has recently been made in some detail with regard to results obtained with electric rotary drills as compared with air drills in some potash mines in central Europe. For the electrical equipment current is distributed through the mine by armored cables fastened to the roof. The motor is furnished with a reversing arrangement, such that two wires of the cable can be interchanged; by this means the rotation field of the motor, and therefore the direction of rotation of the motor, is reversed. The motor has a starting resistance; it develops normally about 1 horsepower, but can be overloaded with 1.5 horsepower for a certain length of time. The connection between drill and motor is made by a flexible shaft. The weight of the drill proper, which is fastened between two screw columns, is 99 pounds. The feed has been varied from 4 to 20 inches in one minute.

In coal mining operations the use of electric rotary drills and augers is quite common, and appears to be thoroughly successful from the fact that the rotary motion of the motor armature can be fully availed of. These drills are used for boring holes into the coal for shooting it down after it has been undercut. Many admirable types of these drills are in wide use. They are so arranged that they can be operated at almost any angle, vertically or horizontally. They are generally mounted on light upright stands, with screws at the ends for fastening to the roof and floor, but some of the larger drills are mounted on trucks, so that they can be transported readily from place to place. The motors, which often are very small and light, not much heavier than a good sized fan motor, are mounted with an adjustable clamp, and are geared for either single reduction or double reduction, for reducing the high speed of the armature to that which is suitable for the auger. The larger rotary drills of this class have been equipped with motors of from 4 to 6 horsepower, the power

being transmitted from the motor to the drill by means of a telescopic shaft and machine cut bevel gears. The telescopic shaft consists of a steel tube in which slide two solid shafts, each of which is fitted with a universal joint, and is fastened to the motor and to the drill machine by means of an automatic coupling.

A number of electric percussion drills, striking a percussive or hammer blow, are in use. They are of various sizes. In some of them the power is transmitted from the motor to the drill by a flexible shaft, which may be several feet in length. In one form, equipped with a self contained motor, the hammer proper is operated by a pair of eccentrics on a shaft connected through simple gearing to the armature of the motor. The raising of the hammer is effected during a three quarter revolution of the eccentric shaft, and the blow is struck during the remaining quarter. A very powerful hammer blow is thus secured, at the rate of about 400 to 500 blows per minute.

The electric method of shot firing in mines has reached considerable development of late years, and is now in general use. There are two methods of electric blasting or shot firing —known as the high tension and the low tension—in ordinary use at the present time. In the high tension method the explosion is caused by a spark which is made to jump between two points inside the detonator. The current for this spark is created by what is known as a magneto machine—an armature revolving rapidly in front of a set of permanent magnets, the whole mechanism being inclosed in a small box from which the handle attached to the armature extends. This box is portable and can be set down anywhere, and the wires from it can be carried a considerable distance. In the low tension method there are employed similar magnetos of low tension, or chemical batteries. In this method the two wires which extend into the charge are connected, or bridged, at their ends within the priming with a short piece of fine platinum or similar wire. This wire offers considerable resistance to the passage of even a small current, so that it rapidly becomes heated to incandescence and thus ignites the priming, which in turn explodes the detonator charge.

The high tension system is in very common use and can be seen in operation in almost any city where building foundations are being excavated in hard material. The low tension system is quite popular in mines, however, the principal reason being, apparently, that the fuses are less subject to deterioration and can be stored more safely than high tension fuses.

The electric locomotive is one of the most striking examples of the application of electricity to mining. The first specifically electric mine locomotive employed in the United States was built nearly twenty years ago by Mr. W. M. Schlessinger for the Lykens Valley colliery of the Pennsylvania railroad, and at last reports this machine was still in service. It weighed about 5 tons and was equipped with 32 horsepower electric motors, from which motion was imparted to the driving wheels by a chain and cog or sprocket connection. The conductor for supplying the current to the locomotive consisted of a light T rail carried on supports parallel to the track at a vertical height of about 5 feet and removed horizontally from the track rail about 20 inches. Current was conducted from this rail by means of three wheels pressed against it by a trolley arm, and the track rails were used as the return circuit. The ordinary train for this locomotive, which operated with a current of 450 volts and from 40 to 200 amperes, was 15 cars, each of which weighed 1 ton when empty and carried 2.35 tons of coal or 3 tons of rock. There were two haulage lines, one 9,500 feet long, in a drift, and one 10,400 feet long, in a tunnel.

Another early electric mine locomotive still in use is of 40 horse power capacity and uses current at a pressure of 220 volts, with a wheel gauge of only 36 inches. This machine is 5 feet 6 inches in height and weighs 10,500 pounds with 1,800 pounds added to increase traction.

Modern mining locomotives range in size—according to the work they are designed to perform—anywhere from 2 to 20 tons, and their wheel gauges range from 18 inches to the standard railway gauge of 4 feet 8½ inches. The traction locomotive consists, broadly, of two iron frames within which are contained the motor and driving mechanism, the controller

wheel being usually placed in front, vertically, within convenient reach of the motorman, who is seated; in some locomotives, however, the controller and hand wheel are placed on the top of the locomotive, in a horizontal position. The motors are usually geared to the truck axles by means of cut steel gear wheels, and the traction wheels are shrunk and keyed upon the truck axles, being placed either inside or outside the locomotive frame. Electric headlights and mechanical brakes are used. The current is taken from an overhead copper trolley wire by a grooved brass trolley wheel, mounted on a short, stout trolley pole, and conveyed through the controller to the motors and back to the generators by means of the track rails, which are copper bonded, in order to insure a return circuit of thorough conductivity. A speed of from 6 to 10 miles per hour is usually made.

Because of the limited dimensions of ordinary mine entries and the light weight of rails, the 20 ton mining locomotive is about the largest that can be used to advantage. Greater hauling capacity is sometimes needed, however, and accordingly a double locomotive has been introduced, consisting of two standard 13 ton mining locomotives, one of which is provided with a 4 motor controller and a 4 motor commutating switch, so that the complete machine is operated from the one controller. Here again, mining practice harmonizes with that obtaining in electric railway work in the adoption of what is known as the multiple unit control, by means of which the control of motors over a whole train of vehicles can be brought to one point and there manipulated by one motorman, instead of being distributed, with each set under the control of a separate driver.

Figures taken from various mines in the coal fields, and compiled by Mr. F. J. Platt, show a generally high degree of efficiency in electric haulage. At the Green Ridge colliery, Scranton, Pa., the cost of haulage by mule power was estimated at 7.15 cents per ton and the cost of electric haulage at 2.76 cents, showing a saving by electric haulage of 4.39 cents. At the Sturges shaft of the New York and Scranton Coal company the cost for haulage by mule power was estimated at 6.58 cents per ton and the cost of electric haulage

at 2.62 cents, showing a saving by electric haulage of 3.96 cents.

A special feature of electric haulage in mines is the use of gathering locomotives. In most coal mines the cars are gathered or collected from the working faces of the rooms by mules or horses, though in some low veined mines where it is necessary to use very small cars they are pushed between the working faces and the room necks by the miners themselves. They are then collected by locomotives and hauled in trains to the tipple or shaft bottom. In many cases it has been difficult to enlarge the entries sufficiently to accommodate the mule, because of the cost of brushing the roof or taking up the bottom, especially where a hard slate or rough limestone has to be dealt with. One means of obviating this difficulty has been found in the use of compressed air locomotives, but electricity has been found particularly suitable for this class of work. Locomotives used for this purpose are equipped with a reel which carries a flexible insulated cable. One end of this cable is connected to the trolley line, and the current is conveyed to the controller on the locomotive through a contact at the reel. The reel is geared up with the axles or truck of the locomotive, so that the cable can be paid out or coiled up. The gathering locomotive system can be pushed to a considerable distance from the end of the regular trolley circuit.

In metalliferous mines, as distinguished from coal mines, the locomotive is usually smaller. An instance of such work is to be found in the haulage system of the United Gold Mines company, of Victor, Colo.—the Cripple Creek district—where one 8 ton locomotive with a draw bar pull of about 3,500 pounds and a speed of from 8 to 10 miles per hour is used. This locomotive is equipped with a single high speed motor placed in the center and on top of the frame, the motor shaft being connected to the drivers by gears. Current for this locomotive is generated at a water power plant 12 miles distant by a 3 phase alternating current dynamo, transmitted at a pressure of 13,000 volts, stepped down and rectified at a substation, and delivered to the trolley at 550 volts direct current.

It is, therefore, not to be understood that electric loco-motives find their only employment in coal mines. An in-teresting illustration of the extensive application of the elec-tric mine locomotive is to be found also in the Quincy copper mine, at Hancock, Mich. The Quincy company has installed 15 electric locomotives, one of which is on the 4,400 foot level, current being supplied from the surface through substation transformer plants located underground. Another instance which might be quoted is the 8 ton mine locomotive at the Highland Boy Gold Mining company's mine, at Murray, Utah, employed for hauling slag cars, and using double overhead trolley, so as to dispense entirely with the track as a return circuit.

Thus far the subject of mine traction has been considered from the point of locomotives supplied by overhead or under-running trolleys, or by third rail, with current from a distant source of supply. It is possible, however, to employ self-propelling or automoblie locomotives, equipped with storage batteries, so as to dispense entirely with the dangers and in-convenience of tracks and wires charged with exposed live current. The weight of the battery and the space that it necessarily occupies, however, increase the size and weight of the locomotives, and thus place a restriction upon this method of traction in many mining operations. Their use is therefore more particularly to be noted in connection with exterior work, and locomotives used for such work have con-siderable haulage capacity.

A further modification of traction or haulage methods is found in the movable automatic loader used by the Illinois Steel company. It is difficult to classify this apparatus, but it serves to move ore, and therefore belongs possibly as much in the transportation as in the loading group. The machine consists of an endless chain of metal arms or scoops mounted on a stout metal table or base, which in turn is mounted pivotally on a truck, to enable it to adjust itself to the pitch of the ground and to the height to which the material is to be elevated in loading—as, for example, to a line of the trolley mine cars. The chain of scoops, which is driven by an electric motor, passes around sprockets ar-

ranged at the opposite ends of the machine. The motor, which takes current through a cable reel from an adjacent trolley or other circuit, also propels the loader, moving it to any desired point by means of chain sprockets and suitable clutches. In operation the front end of the table of the machine is lowered until it rests upon the ground, and it is then thrust forward against the pile of material. As the arm sweeps around each arm or scoop gathers up a certain quantity of material and carries it into channels on the table until it reaches the upper end of the machine, when it is emptied into the desired receptacle. The arms travel at the rate of about 60 to 80 feet per minute, and the capacity of the machine is reported as 90 cubic feet of loose material per minute. This machine is said to have been tested successfully in the handling of limestone, coal, and salt, and to have shown a considerable saving of time and money over hand labor with a shovel.

An interesting and novel application of electric traction methods is to be found in the modern telpherage system. Up to the present time haulage of ores and other raw material in connection with mining work has often been conducted aerially, by means of a traveling wire rope or cable; and this use of the wire rope represents, in the aggregate, an enormous amount of work. As generally understood, a short stretch of such work, often with a span of several hundred feet between the supports, or between the support and the anchorage, constitutes a cableway; in this manner a river or a wide valley is bridged. A tramway cable, on the other hand, has frequent supports, and may be several miles in length. Electric telpherage belongs generically in the latter class, as it is not suited to very steep grades.

The fundamental difference between electric telpherage and the traveling rope system is that in the former case all the ropes or cables are stationary, the haulage being effected by means of an electric motor or telpher traveling along one of the cables, and taking its current, by means of a short trolley pole, from a trolley wire above. In the simpler form the telpher travels along a flexible wire cable; for heavier work a rigid metal rail supported between posts is employed, and.

upon this loads up to 20,000 pounds in weight can be moved at a speed of from 800 to 1,500 feet per minute.

This telpherage method was first experimented with several years ago in England and America, but only within the last year or two has it been practically introduced in this country and abroad. Its present feasibility is due to improvements in motors which can stand exposure, in methods of control, in contact devices, in brackets, etc. In an electric telpher system employed in a limestone quarry in the island of Cuba, the telpher with its car travels upon cables, except at eight curves, where solid rail is employed. The buckets, loaded with limestone and carried below the telpher, take along the cable a maximum load of 1,200 pounds, with a speed of from 12 to 15 miles per hour. Current is derived from a distant power plant, and to start the telpher all that is necessary is to close the switches at the ends of the system. This telpher travels automatically, but in the case of larger apparatus a cab is provided for a telpher man, as on an electric crane, so that he can travel with the load of coal, sulphur, phosphates, etc., and assist in loading and unloading.

Electric hoisting is a growing feature of the use of electricity in mines, and a large amount of work has already been done in this field with the object of replacing the steam engine with the electric motor driven from a central plant. To quote a paper read by Mr. F. O. Blackwell before the American Institute of Mining Engineers, at Albany, in February, 1903, "The throttling of steam to control speed, the necessity for reversing the engine, the variation in steam pressure, the absence of condensing apparatus, the cooling and large clearance of cylinders, and the condensation and leakage of steam in pipes when doing no work are all against the steam hoisting engine. One of the largest hoisting engines in the world was recently tested and found to take 60 pounds of steam per indicated horse power per hour. The electric motor, on the other hand, is ideal for intermittent work. It wastes absolutely no energy when at rest, there being no leakage or condensation. Its efficiency is high, from one quarter load to twice full load." As a matter of fact this class of work touches closely that above referred to in connection

with inclined traction haulage, for after all an elevator is virtually a railway with 100 per cent grade. With these equipments great care is taken to regulate and control the apparatus for safety purposes with safety and emergency brakes, etc.

One of the instances cited by Mr. Blackwell in his paper is that of a flat rope double reel hoist operating in the Free Silver mine, at Aspen, Colo. In this case the hoist works in a vertical single compartment shaft, with guides for extra weight, and is driven by a direct current motor of 120 horsepower at 650 revolutions per minute, with different gears to give 20 and 30 revolutions to the drum. The speed of hoisting ore is from 315 to 630 feet per minute, and that of bailing water from 510 to 1,020 feet per minute.

In one gold mine where steam power has been superseded by an alternating current induction motor, the hoist moves through the shaft at the rate of 1,250 feet per minute, double deck cages carrying 3,600 pounds of ore, thus elevating 500 tons daily from a 2,500 foot level. It is stated that this system has shown a net efficiency of 75 per cent, taking into account all electrical and frictional losses, and that the average cost per horsepower per month has been reduced from not less than $20 to $7.

Electric motors have been found extremely useful and successful in a large number of cases for driving the pumps which are employed to remove the accumulations of water in mines. It is said that the efficiency even of small reciprocating pumps give as high as 90 per cent.

One of the problems encountered in connection with this application of electricity has been the proper regulation of the speed of the motors for the purpose of varying the amount of water pumped. In direct current motors this is done by varying the field strength; the electric pumps which have been in operation for ten years past in the Calumet and Hecla copper mines, in Michigan, have adjustments of speed of 2 to 1 under this system. When induction motors are used the windings are thrown into different combinations for various numbers of poles and rates of speed, and several frequencies, also, are provided for. Some alternating current motors

employed in electric pumping operations are of noteworthy size, developing as much as 650 to 750 horsepower.

For electric pumping the pump itself need embody no special features. Both reciprocating and rotary pumps are used; they may be either horizontal or vertical, and reciprocating pumps may be of either piston or plunger type, according to the circumstances of the installation. Where a reciprocating engine is employed, however, it is generally considered advisable to use a double acting pump, either duplex or triplex. A triplex double acting pump does not require so large a motor as does a simplex acting pump doing the same duty. To raise a great quantity of water against a certain head takes just so much power, but if the work be divided among two or three acting cylinders there will necessarily be a more uniform flow of water, and hence the strain on the motor and the pump will be reduced.

On account of its rotary motion and its high speed, approximating the speed of a motor, the centrifugal pump also is peculiarly suited for electrical operation, the pump and motor being usually direct connected. This pump has been found of special utility in working against low heads and for handling muddy water.

The use of rotary pumps coupled direct to small motors running at high speed in place of reciprocating ram or plunger pumps has met with general approval. These rotary pumps are made with several chambers placed in tandem and are of a type between an ordinary centrifugal pump and a form of reverse turbine.

Another type of electric pump is the sinking pump. The electric sinking pump can be lowered from one location to another in much less time than a steam or compressed air pump, and as it can be completely submerged it does not have to be relocated as often as a steam pump. The question of what would happen to an electric motor in a mine if pumps and motors get flooded has often come up. From tests made recently at the University of Liége, Belgium, it appears that a suitably designed polyphase alternating current motor will suffer very little damage. A 3-phase mining motor of a type largely used on the continent of Europe was completely

submerged in water. It was run for a quarter of an hour; it was then stopped and allowed to remain submerged, under official seal, for twenty four hours, at the end of which time it was again run for a few minutes. It was next removed from the water, again put under seal, and left to dry for twenty four hours. The insulation was then tested, and the motor was found to be in perfect order. It would be hard to imagine a test more severe than this.

As bearing upon this question it is interesting to note that among the pumps in use around Johannesburg, South Africa, at the beginning of the Anglo Boer war, there were twelve of a well known American make, each of which was operated by a 50 horsepower induction motor of American construction with three 15-kilowatt transformers. When the mines were shut down, upon the breaking out of the war, the water rose so rapidly that it was impossible to remove the pumps, motors, transformers, etc., and consequently they remained under 500 to 1,000 feet of water. Two and a half years later, when peace was declared in South Africa, the water in the shaft was pumped out and the electrical apparatus was removed to the surface. Three of the motors were stripped and completely rewound, but to the general surprise of the experts the condition of the insulation indicated that the rewinding might not be absolutely necessary. Accordingly the other nine motors were thoroughly dried in an oven and then soaked in oil. After this treatment they were rigidly tested, proved to be all right, and were at once restored to regular service in the mine. The transformers were treated in the same manner as the motors, with equally gratifying results.

From the earliest days of practical electric lighting, the availability of the method for mining was recognized; and electric illumination in some form or other is now used very widely. Of the two forms—the arc and the incandescent —the latter is very naturally preferred underground, for various reasons. In the first place, the subterranean spaces to be illuminated are restricted in area, so that small lights are sufficient; in the second place, both the earlier arc lighting circuits and a great many of those in use to-day have involved

the employment of dangerously high pressures; and in the third place, there is objection to employing underground an open-flame lamp, such as the ordinary arc lamp has always been. Hence, while a large number of mining plants utilize arc lamps, these are to be found above ground, while the lighting below the surface depends upon incandescents. The advantages claimed for incandescent electric lighting are: The flexibility of the system, making it possible to move circuits readily from one part of the mine to another, the absence of fumes and smoke, less danger of fire, decreased cost, generally better lighting, and reliability of the light under all the variations of temperature and barometric pressure.

It follows that the electric lighting in mines is usually of a composite type, the arc lamp being used at the surface in buildings, yards, sidings, outworks, etc., while the incandescent lamp is used in the mains, levels, tunnels, etc. At one time, in order to accomplish this dual purpose, it was necessary to install two types of generating dynamos—one for the high pressure arc lighting and the other for the low pressure incandescent lighting; but the later developments and improvements in arc lights have made it possible to operate them on the same circuit as the incandescents and in conjunction with motors, and hence recent years have seen the installation of standard types of direct current dynamos for all services, operating at voltages of 100, 220, 550 volts, etc.

One feature of electric lighting worthy of note, but not of great importance, is the use of portable miners' lamps. A great many efforts have been made in this direction with electricity, the lamps depending for their supply of current upon either primary or storage batteries. In either case, the drawbacks have been the weight, delicacy, high cost, and uncertainty of the apparatus, and the fact that such lamps are not usually of the safety type by which the presence of choke damp or other dangerous gases is revealed. In connection with these portable electric lamps for miners, small bulbs and filaments are used, so as to reduce the consumption of current to a minimum, thus making the batteries last longer.

A considerable amount of work is done in mines to-day in the way of ventilation by electric motors, the driving of ventilating fans and blowers by electricity having been found to possess many advantages. In addition to the large amount of work done in tunnels, there is considerable work done in galleries in the way of operating the main fans or blowers for the general ventilation of mines. The larger fans of this class are belt driven, on account of their very low rates of speed, but the smaller ones are also to be found, direct connected to the motors.

The amount of placer mining work that has been done by electricity of late is considerable, particularly in the western states. The best way to afford an idea of work of this character is to cite some of the later examples.

The Gold Pan Mining company, of Breckenridge, Colo., which has the largest placer mining plant in the state, if not in the United States, depends chiefly upon electricity for its operation. The current is generated at a plant some 5 miles from the deposits and is carried to a substation at the mine at a line pressure of 10,000 volts, 3-phase alternating. It is used principally for the driving of pumps and the illumination of the works. Large bowlders are moved by two electrically driven portable cranes of the boom type, which use alternating current from the line, without transformation, and each of which is equipped with a motor capable of developing 30 horsepower. A large 150 horsepower constant speed motor is used to drive a centrifugal pump which assists in keeping the pit dry. A large machine shop, in which are made the large wrought steel water mains employed in the placer system, is supplied with power by a 50 horsepower constant speed motor.

In California the earliest placer mining, represented in a later stage by hydraulic working, upon which legislation imposed severe restrictions, has been largely superseded by dredging, which appears to have developed into a very profitable enterprise where power can be obtained cheaply. In fact, it is stated that, with cheap electric power dredging, land in which the gold averages less than 10 cents to the cubic yard pays for treatment.

The gold bearing placer soil of California has a depth of from 10 to 50 feet, being a gravel deposit left in the old river channels. After one or two holes have been put down by drills, for test purposes, and an analysis of gold bearing soil made, the dredges are put to work, should conditions warrant it. Two types of electric dredges are used to secure the gravel for treatment. In one method the gravel is lifted through centrifugal pumps, while in the other—the method more generally used—it is handled by an endless chain of buckets.

The method of operation is very interesting. A boat is built in the basin or excavation where the operations are to be carried on, the necessary equipment is put on board, and the hole is then filled with water to a depth of from 25 to 40 feet. Current is brought to the operating motors on the boat by means of overhead wires and cables, the cable being usually run out from 400 to 500 feet from the shore. As a general thing, the current used is high pressure, alternating 2 or 3 phase, and the transformers for receiving it and stepping it down for use, although sometimes put on the boat, are generally placed on the bank, on a pole, or in a small substation. The dredge digs its own channel ahead of it, depositing behind it the soil which has been worked over. It may thus be said to carry its own pool with it as the work shifts from point to point. The gravel is elevated into a grizzly, or similar device, where the rocks are washed out of the soil and delivered to the carrier, which deposits them on the dump behind the dredger. The fine soil is next washed through shakers and riffles, the gold being deposited on saving tables, to be taken up with quicksilver, while the worked over soil is deposited at the stern of the boat with the other residue.

Some idea of the character of the work may be formed from the equipment of the chain bucket dredge operated by the Butte Gold Dredging company. This dredge, which has a draft of 5 feet and is about 36 by 90 feet on the water line, is fitted with two spuds, each 50 feet long; one, of wood, weighing about 10 tons, and the other, of steel, weighing about 17 tons. The swing permits of a cut about 90 feet in width. There are 85 buckets to the chain, each bucket having

a capacity of 5 cubic feet. The dredge is operated at a normal speed of 22 buckets per minute, and ordinarily will handle from 50,000 to 75,000 cubic yards of raw material per month. The stacker at the stern of the boat is about 90 feet long and 2½ feet wide.

The largest dredge yet installed is that of the Ashburton Mining company, near Folsom, Cal., with 7½ foot buckets. Some idea of the electric power equipment may be formed from the fact that the induction motors for this dredge include one of 150 horsepower for the digger or bucket line, one of 20 horsepower for the winch, one of 75 horsepower for the centrifugal pump, one of 20 horsepower for the stacker, and one of 10 horsepower for the deck pump.

In addition to the more important applications of electricity to mining, already described, numerous applications of a miscellaneous character might be mentioned. The flexibility of electric circuits and the general adaptability of electric power have led to a wide range of applications, some of which are still in the experimental stage, while many others have already proved successful.

An instance may be found in the substitution of electric motors for steam power for driving air compressors, where the latter are still used for the operation of small tools, coal cutters, drills, etc. By this means the compressor can be placed conveniently near the point of application of the air, so as to avoid long and complicated systems of piping, with consequent inefficiency and heavy loss, whether of steam or of air. Electrically driven compressors sometimes have belt connections, but in many instances the motor and compressor are more directly connected. An alternating current induction motor having a capacity of as much as 200 horsepower has been connected to the air compressor by spur gearing. In one California mine the installation of an electric motor to take the place of steam power for driving a 100 horsepower air compressor is reported to have reduced the average cost of operation per month from $1,800 to $672.

A novel and interesting application of electricity to mining is furnished in the large sand wheel equipment at the Calumet and Hecla mine, driven by a 700 horsepower

induction motor. To the rim of this wheel, which revolves in its pit at a speed of ten revolutions per minute, are attached about 550 buckets for lifting the sand from the copper ore crushings. The electric sand wheel is considered to effect a considerable economy over the previous methods.

Signaling in mines requires a great variety of apparatus such as telephones, telegraphs, bells, and appliances for sending signals according to the indications upon a dial. Of late years the telephone has gained ground rapidly over other methods of signaling. Several telephone manufacturers in the United States make types of telephones intended for mining work, with special regard to conditions of exposure, damp, etc.

In addition to the apparatus already described, a variety of appliances are employed for counting wagons, indicating the level of the water, and kindred uses.

IRON ORES.

BY JOHN BIRKINBINE.

[John Birkinbine, president of the Franklin institute; born in Pennsylvania, 1844; educated at Polytechnic college of Pennsylvania; became assistant engineer with the Philadelphia water works in 1870, and since has been the leading American authority on this branch of engineering, having designed and constructed important water supplies, water power and blast furnaces; is expert on iron and manganese ores for the United States geological survey; president American Institute of Mining Engineers, 1891–3.]

The phenomenal record made in producing pig iron in the United States naturally invites attention to the materials entering into the manufacture of pig metal, the character of these materials, and the sources from which they are obtained. Fuels, iron ores, and fluxes, components of commercial pig iron, in passing through blast furnaces, produce either pig iron in merchantable form or liquid metal, to be carried to Bessemer converters or open hearth furnaces. In 1902 an effort was made on behalf of the Canadian government in equating bonuses to iron industries, to discriminate against liquid metal being classed as pig iron, but the contention was not sustained, and commercially the entire product of blast furnaces smelting iron ore is considered and reported for statistical purposes as pig iron.

In the manufacture of pig iron a considerable quantity of rolling mill cinder, roll scale, etc., is produced, which is also employed practically as ore. Some blue billy or purple ore, resulting from the calcination of pyrites and the residuum from roasting ferriferous and manganiferous zinc ores, are also utilized. Some iron ore is employed for other purposes than for the manufacture of pig iron. It forms an important part of the charge of many open hearth steel furnaces, and is used also for fix in puddling and other furnaces, for flux in silver smelting, and in making metallic paints.

The active demand for iron ore to maintain in operation the blast furnaces of the United States, and the expectation that this demand would continue, was responsible to a great extent for the phenomenally large output of the iron ore

mines in recent years. Large stocks of ore accumulated at or near blast furnace plants aided in swelling the total iron ore supply to figures never before reached.

Iron ore may be considered in four general commercial classes, as follows:

(1) Red hematite, including all anhydrous hematites, known by various names, such as red hematite, specular, micaceous, fossil or slate iron ore, martite, blue hematite, etc.

(2) Brown hematite, including the varieties of hydrated sesquioxide of iron, recognized as limonite, goethite, turgite, bog ores, pipe ores, etc.

(3) Magnetite, an ore in which the iron occurs as magnetic oxide and which includes some martite, mined with the magnetite. Martite is a red hematite ore which preserves to a varying extent the crystalline form of magnetite, but which is nonmagnetic, or nearly so.

(4) Carbonates comprise those ores which contain a considerable amount of carbonic acid, such as spathic ore, blackband, siderite, clay ironstone, etc.

This classification is to be considered as general, the ores having various local or trade names. Thus the prevailing color or general physical appearance is used to indicate an ore, as blue, black, red, or brown, micaceous or glistening hematite. The term specular, although more properly applied to a glistening ore, is by custom given to many dull red hematites. Other hematites receive designations according to their topographical or geographical occurrence, as fossil, mountain, or valley ore, or to the structure, as flaxseed ore, slate ore, etc. In the brown hematite class limonite, turgite, etc., are mineralogical terms referring to the degree of hydration, but the physical structure and appearance of some of the ores are described by the term lump ore, pipe ore, botryoidal ore, needle ore, etc., The beneficiating of brown hematites has given rise to the terms wash ore, sand ore, etc. The carbonate ores are known as spathic ore, limestone ore, blackband ore, kidney ore, etc.

The association of other substances with iron also furnishes names to certain ores, such as pyrite, pyrrhotite, ilmenite, chromite, etc., but in this discussion it is not essen-

PRODUCTION OF IRON ORES IN THE UNITED STATES, GREAT BRITAN AND GERMANY

1889 1890 1891 1892 1893 1894 1895 1896 1897 1898 1899 1900 1901 1902

MILLIONS OF LONG TONS

————— TOTAL PRODUCTION OF UNITED STATES
— — — PRODUCTION OF GERMANY
· · · · · PRODUCTION OF GREAT BRITAIN
—x—x—x PRODUCTION OF LAKE SUPERIOR REGION
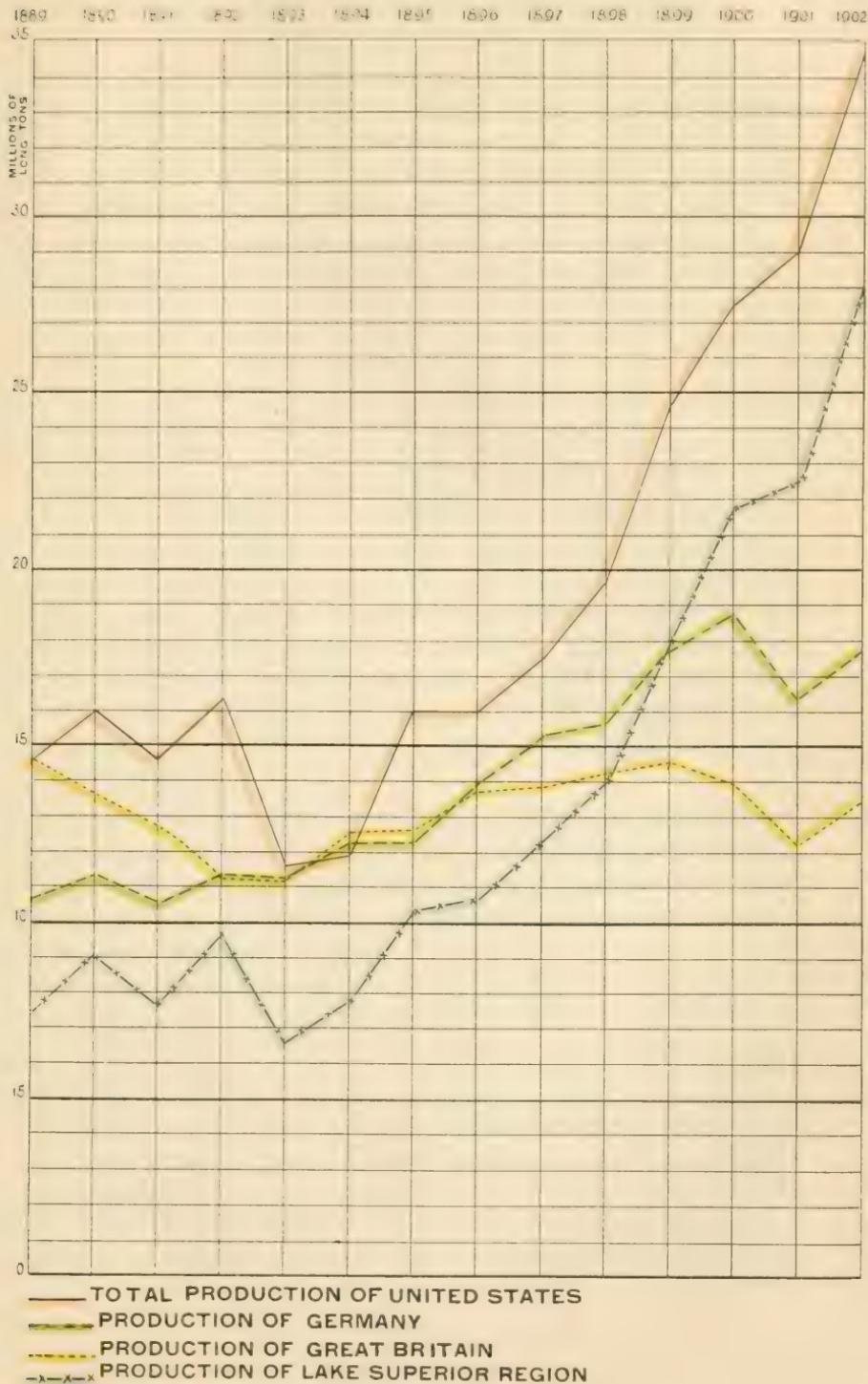
tial that either the chemical, mineralogical, or physical features of the various ores should be considered in detail.

The early iron industry of the United States was based largely upon bog ores, limonites, or other forms of brown hematites, obtained at points convenient to the Atlantic seaboard. Magnetites also were employed at first by means of a direct process whereby, in Catalan forges, the ores were reduced and the resulting metal forged into blooms or billets without passing through the casting process; subsequently, magnetites as well as hematites were smelted in blast furnaces. But the later development of the iron industry and present great importance are due largely to the use of red hematite ore.

The brown hematites and red hematites are of the same chemical composition, in so far as iron oxide is the basis of the ore, the primary differences being structural and the lower percentages of combined and hygroscopic water in the red hematites. Red hematites, if free from other impurities, will yield 70 per cent of iron, and pure brown hematite, if thoroughly dried out and calcined to eliminate all water, will also yield the same proportion of iron. But if the ores are merely dried to drive off the moisture, which differs under varying conditions, the amount of metallic iron possible in a pure red hematite is about 70 per cent, and in a pure brown hematite 60 per cent.

Magnetic ores are capable of yielding in the pure state more metal than any other ores, and pure magnetite would show 72.48 per cent of metallic iron, but magnetites, like the hematites, are subject to deterioration from other elements which are present.

The fourth form of iron ore is the carbonate or spathic, in which the oxide of iron is associated with carbonic acid and generally with lime. If this carbonic acid is driven off by heat carbonate ores become practically brown hematites, but in the natural state the purest carbonate would not yield over 46.7 per cent of iron. Considerable of the early iron industry, particularly in western Pennsylvania, eastern and southern Ohio, Kentucky, and Maryland, and also to a certain extent in eastern New York, was based upon the use

of carbonate ores, but because of the facts that these ores in their natural state are lean, that they usually occur in veins that must be worked underground, often deteriorating as workings are extended, and that the ore must be roasted, the quantity of carbonate iron ores employed has been greatly reduced.

In late years the quantity of magnetic iron ores utilized annually in producing pig iron has increased but slightly, although some remarkable deposits of these ores are available. But magnetites are not as readily reduced as the hematites, are often dense and hard, are liable to have an excess of sulphur, phosphorus, or titanium, or are so closely associated with the gangue matter as to make them lean, demanding that roasting or some method of concentration, either by hydraulic or magnetic separators, should be employed.

Brown hematites occur mostly in pockets or lenses, but are occasionally found in strata, often associated closely with limestone, and also more or less intimately mixed with clays and siliceous matter. Consequently, many brown hematites require washing to separate the clay and sand, and in some cases this washed ore is subsequently roasted to drive off the excess of moisture.

All methods of beneficiating ores, such as roasting, washing, and separating, add to the expense of production, and it is therefore not surprising that red hematites, which seldom require preliminary treatment, have met with general favor.

The distribution of iron ore throughout the United States is general; there is no state in which iron ores of some kind are not found in considerable quantities, but all are not available for use.

In some cases the ores are too lean, that is, carry too small a percentage of iron; in others deleterious elements, such as phosphorus, sulphur, silica, and titanium, are in excess. Some deposits are too far from desirable fuel, or too inconvenient to blast furnaces, to make their immediate utilization practicable; others are in small bodies or veins, or are scattered over too large areas to make their exploitation profitable. It is probable that some of the undeveloped

deposits may be exploited in the near future as the development of newer sections of the country makes fresh demands for iron, or as the extension of railroad facilities and water transportation brings the ores and fuel into convenient association. Improvements in smelting and fluxing ores, which are now considered undesirable because of the presence of some of the elements mentioned above, may also make the production of satisfactory metal from these ores a commercial possibility. While the manager of a smelting plant can obtain ores high in iron, or those which need no beneficiating treatment, at prices which permit him to produce metal at a satisfactory profit, he can not be expected to consider favorably supplying the blast furnaces under his direction with inferior raw material. But the rapid increase in the output of the blast furnaces to meet the growing demands of a developing country may in the near future encourage the utilization of ores which are now considered undesirable.

The greatest development of iron ore deposits in the world is in the Lake Superior region. No other section of the United States, and no other district in the world, has shown such marvelous development or produced so much iron ore as the region embracing parts of northern Michigan and Wisconsin and the eastern portion of Minnesota. Whether in the same extent of territory elsewhere there may or may not be larger deposits of iron ore of equally desirable composition can not be asserted, for it is by development that these great properties have become known and their reserves approximately determined. But to-day the Lake Superior region stands in a unique position by reason of the large quantity and generally superior character of iron ores won from the five ranges or subdistricts which it embraces. Some of these mines have been in operation for fifty years, a number of them for half that time, but the largest annual producers are later developments.

The mines of this region are located at an elevation of from 1,000 to 1,500 feet above Lake Superior, the distance from the lake varying from a few to a hundred miles. The output finds cheap transportation, for the rail haul to the lakes has grades favorable to the traffic, and on the lake shores

expensive and well equipped docks have been constructed at seven different ports, where the ore coming in train loads is received into bins, and delivered from the bins by gravity into the holds of vessels. The vessels take the ore from the shipping docks and carry it through two or more of the great lakes to receiving docks where equal facilities for unloading by mechanical appliances have been provided. In this way enormous quantities of ore are handled cheaply and expeditiously.

The Vermilion range, in Minnesota, was opened in the year 1884. The ore which is here produced is a hard specular, high in iron, and usually of Bessemer grade. This range is the farthest removed from the principal pig iron producing centers, and the high esteem in which the ore is held is shown by the fact that much of it traverses a distance of over 1,000 miles to points of consumption. The two principal producing mines in this range are known as the Pioneer and the Chandler.

In the summer of 1903 the Lake Superior Iron Mining company, a pioneer of the region, celebrated the fiftieth year of its activity, and the following statement made by me for that occasion emphasizes the development referred to:

"Neither the records of the production of the Lake Superior region nor the annual reports of the American Iron and Steel association go back beyond 1854; therefore no data earlier than this will be exact.

"In 1854 there was one mine reported as operating in the Marquette range, the shipments amounting to 3,000 tons. In 1902 the shipments of the Marquette range were 3,868,025 tons, the lake shipments from all ranges in that year reaching a total of 27,039,169 tons.

"The production or consumption of iron ore in the United States in 1854 can only be estimated from the quantity of pig iron made. According to the census statistics of 1850 there would have been in the neighborhood of 1,500,000 tons of iron ore consumed during that year, for there was made in the country 563,775 tons of pig iron. In 1854, according to the reports of the American Iron and Steel association, 736,218 net tons, equivalent to 657,337 gross tons, of pig iron required about 1,750,000 tons of iron ore, whereas in 1902 the country

produced 17,821,307 gross tons of pig iron, and the domestic output of all the iron ore mines in the country for 1902 was 35,567,410 long tons.

"At least 137 producing mines are now active in the Lake Superior region, a number having exceeded annual outputs of 1,000,000 tons, and one mine has approximated 2,000,000 tons in a year. The estimated iron ore production of the country in 1854 approximated 1,750,000 tons, based upon the reported pig iron production, and the yield of ores did not exceed an average of 40 per cent of metallic iron. Therefore, it is doubtful if in 1854 the United States produced as much iron ore as the Fayal mine in Minnesota did in 1902, which in that year shipped 1,919,127 tons. Considered on the basis of metallic contents, however, this output of the Fayal mine probably produced as much pig iron as was made in the United States in any year up to 1866."

Next to the Lake Superior district in order of present importance, basing such importance on the quantity of iron ore produced, is the district of which Birmingham, Ala., may be considered the business center, embracing northern Alabama, part of northern Georgia, and part of southern Tennessee. The bulk of the Alabama ores are red hematites, these ores being largely mined convenient to Birmingham. There is, however, a considerable quantity of brown hematite mined in Alabama and also in Georgia and Tennessee.

Apparently the largest development of the hematite ores flanking the Allegheny mountains exists in Alabama, where the red hematite (known locally as Red mountain ores), obtained in large quantities close to deposits of coal suitable for the manufacture of coke, have encouraged the growth of the iron industry. The red hematites are locally recognized as soft and hard ores; the former, being at or near the surface, are partially decomposed; the latter are mined by underground workings and may be subdivided into siliceous ores, in which silica is present in quantity, and limey ores, in which the proportion of lime may be such as to make the ore approximately self fluxing. Nearly parallel with the Red mountain deposits are important beds of brown hematite and limonite ore, occurring in isolated deposits, some of large extent. In

fact, the exploited brown hematite deposits of this region are of greater average extent than those found in other portions of the country. Occasional deposits of magnetite are also found in the Alabama-Tennessee district, but few have been worked. Some carbonate ore has also been won and used in the manufacture of special irons.

Magnetite iron ores are produced chiefly in New York, New Jersey, and Pennsylvania, but some are won from North Carolina, Michigan, New Mexico, and Utah. The deposits of this class of mineral in New York state are phenomenally large, and so far as metallic contents are concerned, unusually rich; but many carry phosphorus, sulphur, or titanium in excess, some of the most extensive deposits having so much titanium that they have not been brought into commercial use. High phosphorus ores, however, have been and are mined to a large extent, and beneficiated by magnetic concentration. Some ores in the vicinity of Port Henry, N. Y., carry as high as 3 per cent of phosphorus, as apatite, mixed with the magnetic crystals, which, after the ore is comminuted, can be readily separated, either by magnetic separators or by jigs. Other ores of the Port Henry mines district are of Bessemer grade, and from one opening 30,000 tons of very high grade magnetic ore were obtained. This ore approached chemical purity, was of Bessemer grade as to phosphorus contents, and was practically a mass of well defined octahedral crystalline forms, some an inch and a quarter on the face, many having practically perfect proportions. Still larger sized crystals have been found, but these were more or less imperfect, and masses of crystals affected by pressure had some faces flattened.

The localities which have been worked in the Lake Champlain district are the mines at Chateaugay, west of Plattsburg; the mines at Moriah, west of Port Henry; and those west of Crown Point. These deposits are at elevations of from 600 to 1,000 feet above the level of Lake Champlain, and while some explorations originally developed beds of considerable size by an open cut, most of the mining is now underground, and much of it at a depth of 500 feet or more. Some mines which have been exploited are adjacent to the shore of the

lake, others are close to the Adirondack mountains, and some are on the western side of the range. Prominent among the titaniferous ore deposits are the Split Rock mine, on Lake Champlain, and the Adirondack Village mine, close to the main Adirondack range. These titaniferous ores were utilized in former years by the Catalan or direct process, in which the ore was converted into metal by charcoal in open hearths.

The Port Henry mines, located at Mineville, near Lake Champlain, in Essex county, have long been famous as a source of iron ore supply; it is claimed that the first ore was taken out in 1804. The ore is a dense magnetite. It is estimated that there are in the pillars of this mine and of the mines adjoining, at least 800,000 tons of ore. The deposit is very large, having a thickness in some places of 400 feet. The ore bodies are divided into two parts by a horse of rock, and at the lower depth diamond drillings have indicated the existence of two underlying veins of ore high in iron and phosphorus and low in silica. The ore which is sold in the market is high in iron, but also contains phosphorus in the form of apatite, making it all of non-Bessemer quality.

New York is one of the few states where, in addition to the magnetites, the three other varieties of iron ore are found. Red hematite is mined from the north central portion of the state, in Jefferson, Clinton, and Oneida counties; brown hematites are won in the southern portion, east of the Hudson river, in Dutchess and Columbia counties, and in the same district carbonate ore has been found to a considerable extent, and a large plant for roasting these ores has been constructed near Catskill Landing.

Some of the brown hematite mines along the Harlem railroad have been worked for many years, and have been, and are still, the main reliance of the charcoal iron industry along the Connecticut and New York boundary. This same class of ores extends into Litchfield county, Conn., and Berkshire county, Mass., the district being generally recognized as the Salisbury region. The rapid denudation of available timber, and the necessity of operating small blast furnace plants producing a special grade of pig iron, has reduced the number of furnaces, so that now only a few are making iron with

charcoal; these smelt brown hematite and some carbonate ores.

In addition to the brown hematite ores mentioned as occurring in southwestern Massachusetts and northwestern Connecticut, bog ores are found in eastern Massachusetts, and were the foundation upon which the first practical development of the iron industry in the United States was based. Magnetic ore occurs in Rhode Island, and magnetites and brown hematites have been mined in Maine and Vermont.

The magnetite ores extending from New York across northern New Jersey into Pennsylvania, have been liberally developed in a number of locations in New Jersey. The importance of the industry, however, has declined in late years, the bulk of the product being confined to a few of the more important mines. As a rule, the ores of New Jersey are lean, and some of them carry sulphur or phosphorus in excess, but others are of Bessemer grade.

Pennsylvania, although not the pioneer in American iron industry (its initial enterprise having been established about 1716), rapidly advanced to first place, and by reason of the wide distribution of all classes of iron ore and abundance of fuel, became the largest producer of iron, and still holds that rank, although the bulk of the iron ore used in the manufacture of its iron and steel products is mined outside of the state.

The most important iron mining operation in Pennsylvania is that carried on in the Cornwall ore deposit in Lebanon county, which has produced about three fourths of a million tons annually, and, since the year 1740, has contributed a total approximating eighteen million tons to supply Pennsylvania iron works. This ore as mined yields on the average about 46 per cent of iron, carries about three fourths of 1 per per cent of copper, and about $2\frac{1}{2}$ per cent of sulphur. It must, therefore, be roasted, and ore roasting kilns have here obtained their largest development. Furnaces of the Gjers cylindrical form, using solid fuel, are used at some plants, and at others there are circular or rectangular kilns heated by producer gas after the Davis-Colby patents.

The Cornwall ore bank, at Cornwall, Lebanon county, is a large deposit of magnetite from which immense quantities

CLASSIFICATION OF IRON ORE PRODUCTION: 1889 TO 1902.

MILLIONS OF LONG TONS

YEAR

RED HEMATITE

BROWN HEMATITE

MAGNETITE

CARBONATE
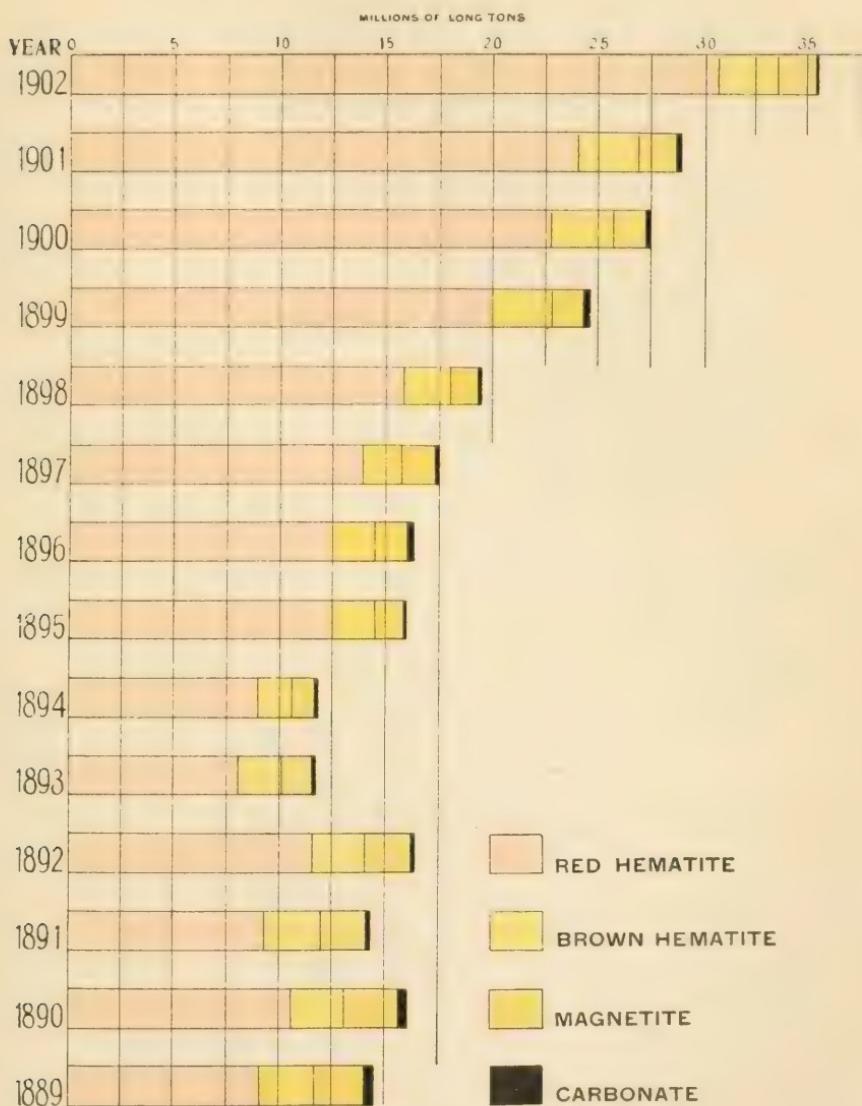
of ore have been won. Most of the ore is obtained above water level, cars being run in on a series of terraces. The ore is broken down and loaded onto cars by means of barrows, and thus transported to the furnaces.

Along the South mountain, from the Delaware river to and beyond the Susquehanna river, deposits of magnetic iron ores are found and have been worked. In Lehigh and Lancaster counties at present they are mined chiefly for concentration, as the ore is lean.

Along the northern and western faces of the South mountain, and in the valley between the South and North mountain ranges, brown hematite ore has been mined in many localities, some of the deposits having been worked on a liberal scale, and others, producing but little, have a history approximating a century of time. As a rule, these brown hematites require washing to make them desirable for blast furnace purposes, and they yield, after such treatment, about 45 per cent of iron, some with 2 to 5 per cent of maganese, and all with phosphorus above the Bessemer limit.

In the bituminous coal belt, which extends across Pennsylvania from northeast to southwest, with the Allegheny mountains as an axis, the carbonate ores obtained were formerly an important base of supply. The location of many of these ores in small veins, the exploitation of which is expensive, the necessity of roasting them, and their generally high phosphorus content have much limited their use.

In Delaware there are several isolated deposits of brown hematite which have been worked but are now inactive. In eastern Maryland carbonates which occur mixed with clay are mined in a desultory way by farmers and used near the city of Washington to produce a special grade of pig metal with charcoal. In western Maryland there are brown hematites, and some lean magnetites, which, while appearing to occur in large proportions, would have to be concentrated to be merchantable.

In Virginia the bulk of the iron ores mined are of the brown hematite class, some occurring in beds of clay, others in a form approaching veins embedded in rock strata. Minor deposits of red hematite also exist, and in southwestern Vir-

ginia and in western North Carolina there are large bodies of magnetites. Titaniferous magnetites and brown hematites occur in central North Carolina and extend into South Carolina, Georgia, Tennessee, and Alabama.

The Appalachian mountain chain is bordered by iron ore deposits from northern New York through New Jersey, Pennsylvania, Maryland, the Virginias, North Carolina, Tennessee, Georgia, and Alabama. These deposits are mostly magnetites and brown hematites, the latter generally showing in the valleys, the former often in foothills or on the slopes of the mountains. Some red hematites are also found on the mountain slopes. Nearly paralleling the Appalachian range, and occupying positions in the foothills of the Allegheny mountains, are deposits of brown hematite, also of carbonates. The carbonates are more abundant in the coal bearing regions, and occur on both flanks of the Allegheny mountains.

Still farther west carbonate ores and some brown hematites are found in the coal measures of western Pennsylvania, West Virginia, Ohio, Kentucky, and eastern Tennessee; red and brown hematite are abundant in Kentucky and Tennessee.

The ores obtained from Ohio and from the portion of Kentucky adjacent to the Ohio river are either carbonates or hematites, resulting from the weathering of carbonates; these have sustained a considerable iron industry for many years in southern Ohio and in Kentucky, in a locality known as the Hanging Rock region, with Ironton, Ohio, and Ashland, Ky., as business centers.

There are also in Kentucky excellent deposits of limonite, and these extend into Tennessee, some quite important mines existing in the central and western portions of the state. There are also carbonates in the southwestern section which extend into Mississippi. Carbonate ore also exists in northern Florida.

The liberal exploitation of the iron ores in the Lake Superior region has directed attention to deposits in adjacent states. In central Wisconsin brown hematite exists in pockets or lenses. In southern Wisconsin there is a unique deposit of high phosphorus red hematite ore, which, owing to its physical structure, is known as flaxseed ore, and an appar-

ently large quantity of red hematite of excellent composition has also lately been discovered by drilling and shafting in the vicinity of North Freedom, Sauk county.

Missouri attained prominence as an iron producing state several decades ago through the Iron Mountain and Pilot Knob deposits, which gave promise of being large producers, but as development proceeded these ore beds were practically exhausted, although it is possible there may be undiscovered extensions of them. In central, eastern, and southern Missouri red hematite and brown hematite ores are obtained in quantities, and these ores also extend into Arkansas, although there has been no development in that state.

The exploitations for iron ore in Texas have been chiefly in the northeastern section, where brown hematites have been won from near the surface, and the fact that these lie in nearly horizontal layers, covered but slightly with a ferruginous sandstone and sand, suggests that they are bog ores forming the bottom of an extinct lake. They extend over a large territory, except where the plateaus are cut by water courses. In central Texas an important deposit of red hematite ore, claimed to be of excellent quality, has been opened up, but in the absence of demand for this mineral, exploitation has not been prosecuted.

The section of the country which may be considered as the Rocky Mountain region has a number of important deposits of iron ores and all the general classes of ores are found. In what might be called the distinctively mountainous section, on the western slopes, magnetites are obtained, and some deposits of apparent magnitude are known to exist, but owing to the high elevation of the deposits and the amount of snow encountered, they have not been exploited. It is possible that the increasing demand for iron ores may encourage development.

The iron ore deposits at Sunrise, Laramie county, Wyo., are quite extensive; until late years, however, but little ore had been produced from them. The ore is a red hematite occurring in carboniferous limestone; covers, as it is claimed, a superficial area of about 20 square miles; contains from 60

to 67 per cent of iron from 2.5 to 5 per cent of silica, and is low in phosphorus.

In New Mexico there is a deposit where red hematite and magnetite ores are obtained. The Fierro, or Union Hill, and Jim Fair mines are located in the territory of New Mexico, near Hanover. Mr. D. M. Barringer, M. E., states that the ore generally, but not always, occurs with eruptive granite and limestone, probably carboniferous, the vein being vertical or dipping at a steep angle. The ore of the Union Hill mine is a mixture of approximately 75 per cent magnetite and 25 per cent hematite, and is quite hard.

The ore of the Jim Fair mine is of practically the reverse composition to that of the Union Hill, the greater portion being of the hematite variety, and is also quite hard. Both here and at the Union Hill mine the ore stands in dikes, and is quarried out in open cuts. Mr. Barringer states that at one place there is a large deposit of brown hematite ore, and at one point there is also a considerable amount of specular ore. The ore carries satisfactory percentages of iron, and is of Bessemer quality. The permanency of this deposit does not seem assured from the results of mining operations to date.

In the San Luis valley of Colorado, which may be said to be in the heart of the Rocky mountains, brown hematite ores are mined, and one mine has been phenomenal not only for the quantity taken from it, but also for the low percentage of phosphorus in the ore. In fact, the product has been persistently a Bessemer ore, and it is probable that no other deposit of brown hematite has produced as much low phosphorus ore as the Orient mine. This mine is located in the eastern part of Saguache county, about eight miles from Villa Grove, and was opened in 1882. The ore body is from 30 to 150 feet in width and is worked by means of tunnels, from which stopes are run. Over 1,000,000 tons of ore have been obtained from this deposit, but unfortunately it shows signs of exhaustion. It may be, however, that deposits of similar character will be found in the same district.

Between the Pacific coast and the Rocky mountains there are a number of deposits of iron ore, but few have been exploited, because there has been little or no market for the min-

eral. In northern and southern California magnetites and red hematites are reported, but nothing beyond exploratory work has been done upon them. When satisfactory supplies of metallurgical fuel become available it is possible that some of these Pacific coast deposits may be exploited. Magnetite has also been mined near Lovelocks, Nevada.

The determination of the value of iron ore deposits is difficult, for they are only serviceable in so far as the material of which they are composed may be utilized. Thus, a mountain of excellent iron ore remote from blast furnaces or other means of utilization, without transportation facilities to carry the mineral to points where markets exist, would stand practically useless until these conditions were modified.

The quality of the iron ore obtainable has a decided influence upon the value of the product, and therefore upon that of the deposit. Ores low in phosphorus, although with moderate iron content, command premiums over those carrying this element in excess, and in the present state of metallurgical development ores carrying titanium are considered undesirable, although in the near future they may possibly be sought after. A sulphurous ore requiring roasting is less desirable than one free from sulphur, and ores which require washing or beneficiating, either by jigs or magnetic separators, have less value than those which can be used in their native state. Therefore, the apparent quantity and average quality of an ore in a deposit and its accessibility to markets or prospective points of consumption affect its value. Where a mine is producing and where the tests made to determine the apparent extent of the deposit are satisfactory, its value may be gauged by capitalization based upon a royalty charge for ore mined, for in an ore deposit the material taken out is not reproduced, and therefore some allowance covering a value for the ore won is proper.

The difficulties of determining the value of iron ore deposits are increased by the fact that in some instances mere mining rights are granted, while in others a proprietor may allow a mining company to take ore at a fixed rate per ton, or upon a sliding scale. In still other cases the ownership is in a state which grants mining leases at tonnage rates; these

leased properties after having been explored or developed are sublet, and thus two or more royalties may be cumulative. A deposit of ore has no definite value to the lessee or sublessee, other than what he gets out of it during the term of his lease, for he has no interest in its future and the owner can practically base no estimate of value except by capitalizing its earning capacity, providing that earning capacity can be maintained.   Another feature which has caused trouble in an attempt to determine approximate valuations for the iron ore deposits of the United States has been that a company may own or lease a considerable tract of land only a small part of which has been explored or exploited.   It would be manifestly unfair to base an estimate of the value of the entire property upon results obtained from a limited area.

All of the ore mined in the United States is not utilized in the production of metal for steel manufacture, for in this freedom from phosphorus is generally necessary; an excess of this element, however, is admissible in iron treated by the basic Bessemer process.

For use in foundries, for treatment in puddling furnaces, and for other purposes which, taken together, consume approximately one quarter of the pig iron produced, the limitations as to phosphorus are less rigid.   For these purposes many ores may be smelted which are not considered desirable in manufacturing pig iron for conversion into steel.   However, other elements than phosphorus demand consideration, and in the selection of ores their chemical composition determines their availability for specific use.   The percentage of iron which an ore yields is the first consideration, for upon this the economy of smelting primarily depends, but objectionable elements or oxides may encourage the selection of an ore containing less metallic iron, but freer from objectionable constituents than an ore with high iron contents associated with deleterious ingredients.

Iron ore deposits in the United States vary materially in character, size, and occurrence, and the geological and physical conditions of the several varieties generally known as magnetite, red hematite, brown hematite, and carbonate ores require different methods of exploitation which also vary greatly.

The known character, the apparent dimensions, the general form, and the position of an iron ore deposit, with reference to the surface and water, the physical structure or chemical composition of the material to be extracted, the character of the earth or rock inclosing or occurring in the ore body, the stratification, dip, and strike, the simplicity or complexity of the ore body, the convenience of the deposit to an available market for its product, and the capital at command of those who attempt the exploitation—all influence the methods followed in mining iron ore.

Where the ore body projects above or lies close to the surface, or where in a large apparently well defined deposit the cover can be stripped to advantage, the exploitation may be carried on by open cut work, from which the ore is taken out either by train or, after digging, lifted by steam power applied to inclines or to vertical hoists.

In the Mesabi range of Minnesota, in the Sunrise district of Wyoming, and in a number of brown hematite deposits of the south, large open cuts are worked by the use of the steam shovel, these appliances removing the ore in successive benches after large areas have been stripped by the same method.

Where the body of ore is under considerable cover, if the roof is firm, or if the vein matter is comparatively narrow and the dip steep, it is removed through shafts, either vertical or inclined, and through tunnels or adits. In a number of instances open cut work has, after reaching a considerable depth, been supplemented by underground exploitation, while in a few cases this method has been reversed and a large open cut has supplanted underground work. The shafts or adits, which are generally expected to serve as long as the deposit yields ore, are necessarily costly and need to be planned and located with care, for through these the miners have access to the underground workings, and the ore and water are carried to the natural surface.

Except when the strata penetrated are exceptionally compact and hard, the shafts or adits must be substantially timbered, so that they can be maintained until the deposit is exhausted; they are excavated either in the ore or in inclosing rock, and if in the ore large bodies are left adjacent to these

avenues of approach as a safeguard against accident. From these main arteries drifts are opened either parallel or at different angles in wide or shallow deposits, or at determined depths in narrow and deep deposits, and from these in turn supplementary drifts are run and rooms or stopes excavated.

In deposits dipping considerably from the horizon one prevailing method of exploitation is to open a series of drifts at different levels, from which mining is carried on simultaneously; the upper levels are farther advanced than those below, the ore being taken out in horizontal sections or slices, known in mining parlance as stopes. When the ore is worked above a given level and allowed to fall by gravity, through chutes or otherwise, to vehicles which deliver it to the main arteries, the method is called overhand stoping. Where the material is attacked below a level and the ore raised to this level, the method is recognized as underhand stoping. The overhand system is, under most circumstances, the cheaper and more advantageous, but the underhand stoping is necessary in taking up floors, removing pillars, and in some open cut work.

In underground operations the space made void as the ore is removed must be protected, at least in part, either by timbering or by filling in rock or other waste material. In some instances the ore, if hard and if left in pillars alternating with rooms or stopes, will safely support the roof, but often the proportion of ore sacrificed is too great to make this method desirable.

After shafts or adits have been sunk and main drifts run the ore is taken out by various systems, which may be briefly designated as follows:

Milling, in which the surface earth is removed and the ore drawn through raises into drifts located some distance below the top of the ore, thus making large sinks or craters. This system requires that the cover be stripped, and is especially adapted to moderately shallow deposits of soft ore covering a large area.

In caving, a series of levels connecting with the main shaft or with several shafts are simultaneously worked, the ore being taken out from the upper levels and delivered through winzes to lower levels which are protected by the ore in situ. As the

ore is removed from the portion of one level the superincumbent rock or earth is allowed to cave upon the ore below, and frequently the settling of the material is facilitated by the use of explosives. By this method but little ore need be left in a deposit, and if care is exercised the risks are not great and but little waste becomes mixed with the ore. This method is applied more to soft or moderately soft ores than to those which are harder, but it is used in some hard ore mines where the roof or hanging wall is insecure.

Drifting is employed in all underground mining, but where a series of parallel drifts, one advanced more than another, are employed to slice off the deposit the method is specifically known as the drifting or slicing system.

Room mining may be considered either as digging out cavities which alternate with pillars, or as opening cavities of considerable length, width, and height, usually from foot wall to hanging wall, and supporting the last named and the roof by an elaborate arrangement of timbers known as square sets, in which the timbers are so placed as to form the outlines of a series of cubes resting upon one another by carefully fitted joints. This method is largely employed in removing soft hematite, and some of the cavities thus made and protected are of enormous size.

Filling is not so much a method of mining as a means of protecting the workings by depositing in the cavities waste rock, sand, and other refuse. This method is often more economical than timber support, and is adapted to hard ore mines.

The magnetites, as a rule, are found in fairly well defined veins, inclosed between walls and dipping at steep angles from the horizon. Some of these veins are of enormous size, as in the Lake Champlain district of New York, where the texture and hardness of the ore permit of its use as pillars in the mines. Other veins are narrow and tortuous, although persistent, and each of these characteristics demands different methods of exploitation.

THE MINING OF IRON.

BY WALDON FAWCETT.

[Waldon Fawcett, author; born Salem, Ohio, February 23, 1875; is one of the most popular contributors to newspapers and periodicals on technical matters, writing for the most part as the result of personal investigations; in this connection he has traveled through the United States and Europe collecting information; also syndicates weekly articles on industrial topics to a large syndicate of newspapers. Author of several works on economic and industrial subjects. The article here published is used by arrangement with the Century Magazine.]

If, in this age of science and invention, there was to be prepared a revised category of the wonders of the world, the first place would unquestionably have to be accorded to the marvelous process whereby the most valuable of the earth's deposits is transformed into iron and steel products for everyday use.

There are so many amazing things connected with the work of taking from the ground the ore, which looks for all the world like rich red earth, and eventually working it up into every imaginable form, from tea-kettles to locomotives, that to put your finger on any one phase of the transformation and say, "This is the most surprising," is next to impossible. Most persons, if they were obliged to choose, however, would select the journey of the iron from the mine to the furnace.

Of the million men employed in the iron industry in the United States it is estimated that nearly two fifths are embraced in the army engaged in the mining and transportation of the ore. These men handle each year raw material which has cost in the neighborhood of a billion dollars, and they receive for the service an aggregate annual wage of close to half a billion dollars.

The industry of mining iron ore has flourished, at one time or another, in considerably more than half of the states of the union; but the discovery of excessively rich deposits in one locality has narrowed down the situation until now nearly all the ore is derived from one region—the richest iron ore field in the world—the region surrounding Lake Superior. It is in the subterranean treasure houses near the northern border

of the country, moreover, that there have been originated those novel methods of mine operation which have caused the mineral world to open its eyes, together with those reductions in costs which have enabled the American manufacturers successfully to compete in the markets of the world. The history of the Lake Superior district, therefore, represents the more striking phases of the development of iron mining in America.

Many estimates have been made of the capital involved in mining the Lake Superior ore and transporting it by rail and water to its various destinations; but even by the most conservative figuring, the sum must be placed in the neighborhood of five hundred million dollars. Upward of one half of this great investment is represented by the one hundred mines, which are now capable of turning out close to twenty million tons of iron ore each year—a product which sells for enough to pay the interest on the public debt of the United States for over two years.

The railroads which carry the ore from the mines to the shipping ports on the upper lakes, and the docks where it is placed aboard the vessels, have cost between fifty and sixty million dollars, and the several hundred vessels employed exclusively in ore transportation from upper to lower lake ports could not be duplicated for three times that sum. Finally, there are the elaborately equipped docks at lower lake ports, where the ore is received, representing an investment of close to eighteen million dollars, and the capital employed exclusively in the railroad transportation of the raw material inland to mills and furnaces adds pretty nearly double that sum to the grand total.

Twenty million tons, which constituted the yearly output of the Lake Superior region at the opening of the new century, is more than double the product of any other iron mining region in the world during any single year in history. Loaded in freight cars of the ordinary type, three railroad tracks would be filled solidly from the Atlantic to the Pacific coast.

The Lake Superior iron mining district is divided into five parts, or ranges, as they are termed in iron circles, namely: the Menominee and Marquette ranges in the state of Michigan;

the Gogebic range, partly in Michigan and partly in Wisconsin; the Vermilion and Mesabi ranges in Minnesota.

There are as many different methods of mining in vogue in the iron region as there are separate ranges, although the various systems are not thus apportioned. Virtually every mine on any of the four ranges other than the Mesabi is worked on the overhead stoping, the caving, or the milling plan. On the Mesabi range the ore is taken out by means of steam shovels. The essential feature of the first mentioned plan is the construction of a timber lined shaft, perhaps twenty feet wide, which is sunk into the earth a distance of two thousand feet or more. Opening from this shaft are tunnels, which are driven horizontally through the deposit of ore, and constitute corridors, along which the iron may be conveyed in cars to the main shaft and thence hoisted to the surface.

The caving method is not very different from that just described. One or more shafts are sunk, and a considerable portion of the deposit is honeycombed with side passages through which the ore is passed to the main artery of communication and thus to the surface. The system derives its name from the fact that, as the ore is taken out, the surface of the ground gradually caves in, forming an immense pit.

The milling system can be employed most advantageously where the ore deposit is located in a hill of considerable altitude. A tunnel, probably twelve or fifteen feet square, is driven into the base of the hill, and connecting with this are shafts sunk directly through the ore from the summit of the hill. Explosives loosen the ore surrounding the perpendicular shafts, and it falls directly down these great chutes into the little cars which are waiting to receive it in the tunnel below.

The greatest measure of the romance of iron mining is bound up, however, in the steam shoveling method of procuring the ore. Open pit mining, as it is called, is not only the best and cheapest of all known processes, but it constitutes one of the most picturesque industrial operations to be found anywhere in the world. Of course, this method of taking out the ore wholesale can be employed only on the Mesabi range, where great deposits occur near the surface of the earth, covered, as it were, by only a thin blanket of soil. The Mesabi

ore, which appears like nothing so much as loose red earth, is found in great masses on the slopes of hills, and virtually the only task before the mine operator is to scoop it up and load it into the cars standing on the siding, which are run into the pit just as cars might be backed into a stone quarry.

Out of some of these immense holes in the ground more than a million tons of ore are taken every year, and it is all dipped up by steam shovels, strange, ponderous machines, with muscles of iron, and engine pulsations serving for heart throbs, but which never grow weary or go on strike, but steadily, hour in, hour out, keep at their task, drawing out five tons of the embryo metal at every upward sweep of each giant arm. Each of these steam shovels weighs more than the average locomotive, and costs more than five thousand dollars.

Ten or a dozen men are required to operate one of these mechanical shovelers, attending to the engine, keeping the fire going, and pressing the levers which send the ungainly looking bucket burrowing into the bank of ore just as the dipper of a dredge might sink into the mud, and the other levers, which call into play the sinews which lift the brimming panful, swing it around, and empty its contents into the waiting railroad car. It usually requires five trips before a car is filled, but the whole operation seldom requires more than five minutes, and very frequently a car is loaded and shoved out of the way in two or three minutes. One of these immense iron ore diggings may occupy a plot half a mile square, and the steam shovels travel back and forth as do locomotives in a railroad yard. On the earthen palisades high above them the dynamiters are at work; and after each blast laborers with pickaxes loosen the ore and let it run down to the shovels.

The unearthing of iron as conducted in the Lake Superior district may be said, with small fear of contradiction, to be characterized by the presence of the spectacular element to a greater degree than any other form of mining. Not even the hydraulic method—employed on an extensive scale in the search for gold in some localities—so strikingly embodies the picturesque, and yet combines with it a forceful demonstration of the wonders of modern engineering science. Perhaps the

immense number of men employed, the mad rush to grasp every possible ton of treasure within a somewhat limited interval of operations, and the extensive scale on which the whole enterprise is conducted, may have something to do with it. Finally, in cataloguing the charms of this great fountain head of the iron industry, it will not do to reckon without the fascination which phenomenal success exerts over the keen, alert American mind. When the visitor to northern Michigan, for instance, is told that he is in the very maelstrom of an industry that is growing at the rate of nearly twenty per cent every twelvemonth—a business the gross receipts of which are bounding upward by two million dollar steps annually in this one state alone—he is apt to share, to some extent, in that enthusiasm which enables the iron operators to work day and night over plans to increase production during the months when other folks are lazying through their summer vacations.

Some remarkable achievements have been placed to the credit of these workers in the northern wilderness. As an example of the rapidity with which mines can be made, there might be cited the case of a property opened near the town of Virginia in Minnesota a year or two since. In less than two months after ground was broken a working shaft had been constructed a considerable distance into the ore, and a second was well under way, machinery had been purchased and was on the ground, a railroad had been surveyed to provide an outlet for the product of the mine, and a small stock pile of the raw material had begun to accumulate. Possibly more wonderful still is the fact that during the very first season the owners sold from this mine over a hundred thousand tons of ore, receiving for it a sum which enabled them to show a profit not only upon the mining, but upon the opening of the property as well.

Even on the Mesabi range, where the boast is made that to get ore it is only necessary to shovel it up, there is much to be done before the big steam shovels can be set to work scooping up the red mass. The coverlet of earth which covers the ore bed may have, in some places, a thickness of only a few feet; but in others the depth of soil may reach thirty or forty

feet, and in order wholly to remove this stratum of earth and boulders, stripping operations on a gigantic scale are resorted to.

Winter holds the iron lands in its grasp during so great a portion of the year that the men who are engaged upon the stripping work have a comparatively brief season of activity. Nor is their work fraught with any particular danger, save that which is always present where large bodies of men are wielding edged tools. It is when the earthen blanket has been torn off, and the great mass of ore, hundreds of feet deep, lies spread out awaiting the shovelers, that the risks of the iron miner's calling begin to present themselves.

The ore must be shaken up ahead of the shovels by the liberal use of powder, and in this necessity for the constant use of explosives is found probably the greatest of the dangers to be braved by the iron miner. For blasting purposes holes several inches in diameter are driven to a depth of many feet by means of pointed steel bars. The dropping of a stick of dynamite serves to enlarge one of these tiny tunnels to pretty fair proportions, and then five or six kegs of black powder are poured in, and there is an explosion which loosens sufficient ore to feed the industrious shovel for some little time. To illustrate what a frightful rending of the earth is constantly in progress in the mining region, it may be noted that even a moderate sized mine will consume, on an average, thirty five kegs of powder a day.

The tremendous demand for iron which has developed during the last few years has worked many surprises in the Lake Superior country. Old stock piles, discarded, because the ore was only of mediocre quality, so long ago that young forest trees were growing on the dumps, were hastily shoveled into cars; mines abandoned because their yield was only moderate, just as the youngster hunting wild flowers is constantly attracted by the wealth of new beds just beyond, were reopened; and, finally, novel schemes have been resorted to in order to enable the miner to secure ore formerly supposed to be inaccessible. On the Menominee range, for instance, the Iron river, a stream of considerable size, is being turned from its present course over a promising bed of ore into another channel some distance away.

When it is explained that in some of the mines surrounding Lake Superior as much as four hundred gallons of water must be disposed of every minute, the reader will appreciate that it is inevitable that there should be considerable moisture in the ore. Naturally this greatly increases its weight, and one of the lines of investigation recently taken up by mine operators has involved experiments in the drying of the ores at the mines in order to effect a saving in freights. It has been found that about ten per cent of water, or nearly all the moisture in the ore, may thus be driven out, and inasmuch as it is claimed that the ore, if once dried at the mines, does not absorb moisture after it is placed in the stock pile, the saving is continued through all the stages of the journey to the furnace.

What might be termed the financial side of the iron mining industry easily constitutes one of its most interesting phases. Here is a commodity which, in its raw state, adds nearly twenty five million dollars to the wealth of the country every year—an aggregate greater than that of the gold and silver mines of the nation. There are mines in the territory bordering on the world's largest fresh water lake which have, in a single year, recently netted their owners a profit of $1,500,000, or half as much again as the authorized capital of the company controlling them, and it is nothing unusual to hear of a mine which has paid for itself in a single season.

MODERN BLAST FURNACE PRACTICE.
BY FRANK HEARNE CROCKARD.

[Frank Hearne Crockard, engineer; is one of the best known metallurgists in the United States, his specialty being the iron industry; he is manager of the Riverside department of the National Tube company's great plant at Wheeling, W. Va.; he has written several articles on the economics of the iron industries for technical periodicals, and among them is the following which appeared originally in the Engineering Magazine, and is printed herewith by special arrangment.]

The last three decades have been epochal in American b.ast furnace practice and construction. The Lucy furnace of Pittsburg may be named as the primordial furnace of the present type. This furnace in the year 1878 had a cubic capacity of 15,400 feet, and was driven at the rate of 16,000 cubic feet of air per minute. The results of the first year showed a daily production of 91 tons, so that each ton of iron required 169 cubic feet of furnace volume. The coke consumption during this period averaged 2,850 pounds per ton of iron. The promising bud of siderurgical progress thus started reserved a later day for blossoming, and this we find in the Edgar Thomson furnace blown in during April, 1880. Furnace B of this group was 80 feet high, and contained 17,-868 cubic feet. The hearth measured 11 feet in diameter and was fitted with eight 5½ inch bronze tuyeres, through which were forced 30,000 cubic feet of air per minute, at a temperature averaging 1,100 degrees Fahrenheit. This furnace produced 132 tons daily, requiring 135 cubic feet of furnace volume per ton of iron. The coke consumption during this period averaged 2,859 pounds. Small as they now seem, these tonnage records were regarded as phenomenal, if not incredible. This period was distinctively, therefore, one of rapid driving, wonderful production, and high fuel, and so continued until the blowing in of the North Chicago Rolling Mill company's Number 7 furnace. This furnace was blown in during March, 1885; for the period covering the last six months of that year the production aggregated 36,680 tons, the average coke for the same period falling

to 1,912 pounds per ton of iron; the rate of driving, which averaged from 22,000 to 25,000 cubic feet of air per minute the previous year, had now fallen to 16,000 cubic feet. This achievement marked the next important step, characterizing the period as one of great production, low fuel, and slow driving. While these results were very gratifying, they proved merely precursory of the greater achievements of the new epoch which has since been seemingly resolved into an interminable era.

In September, 1889, the Edgar Thomson group again forged to the front with the blowing in of an 80 foot stack, containing 18,200 cubic feet. This furnace had seven six inch tuyeres delivering 25,000 cubic feet of air per minute— a return to the figures of 1880, but productive of entirely different results. The temperature of the entering blast remained about the same, 1,100 degrees Fahrenheit, but the pressure had reached $9\frac{1}{2}$ pounds, while the output (for the month of April, 1890) reached 10,075 tons on a coke consumption of 1,884 pounds. In 1880, 135 cubic feet of furnace volume were required per ton of product; in 1890, this figure had fallen to less than 60 cubic feet. Intensity of production was the order of the day, and, thanks to the daring initiative of American metallurgists, has not yet found its prescribed limits.

An interesting example of recent furnace construction is found in the Youngstown plant of the National Steel Co. These furnaces are $106\frac{1}{2}$ feet high, 23 feet in the bosh, and have a hearth diameter of 15 feet, giving a capacity of 26,500 cubic feet. Blast at the rate of 50,000 to 60,000 cubic feet per minute is introduced through sixteen 6-inch tuyeres. The normal pressure is about 15 pounds, but the blowing equipment is designed to furnish 25 pounds when necessary. These furnaces were blown in during 1900; in the month of October of that year one furnace produced 17,600 tons with a fuel consumption of 1,777 pounds per ton; a second stack during the same period produced 17,412 tons with a fuel consumption of 1,790 pounds. Both furnaces lost a day during the month.

IRON AND STEEL PRODUCTION BY STATES

LESS THAN $5,000,000 $5,000,000 TO $20,000,000
$20,000,000 TO $60,000,000 $60,000,000 TO $150,000,000
OVER $150,000,000

BLAST FURNACE AND ROLLING MILL PRODUCTION
PER SQUARE MILE

LESS THAN $10 $10 TO $100
$100 TO $1000 $1,000 AND OVER

While it is true that furnaces of greater (cubic) capacity than the present American furnaces were constructed as early as 1870, as for example the two Ormesby (English) furnaces constructed about that period, which had a volume of about 40,000 cubic feet, as compared with 26,500 cubic feet in the case of the Youngstown furnaces, we find their weekly output equaled by the daily product of the latter. The development then, of the high pressure, high tonnage furnace, as we understand the term to-day, has been accomplished during the last few years. With this increased tonnage, the demand—or rather the necessity—for apparatus supplementing or displacing manual labor grew apace. When we remember that the digestive capacity of one of these monsters, expressed in tons, approximates 2,000 tons daily, the task of supplying its capacious maw is more fully appreciated.

The Duquesne plant of the Carnegie Steel Co. was one of the first examples of this type. A 600,000 ton stock yard, 1,085 feet long, having an effective width of 226 feet, was provided for the four furnaces comprising this group. The stock yard is spanned by three bridge cranes built by the Brown Hoisting Machinery company of Cleveland. During the stocking season, hopper bottom cars are unloaded in bins behind the ore piles. These bins form one of two parallel rows; the row nearer the furnaces is used for supplying immediate demands, while the row facing the stock pile is used for transferring the ore from the cars to the ore buckets, which when filled are picked up by the crane and automatically dumped on the stock piles. The reverse operation is accomplished by means of 5 ton drag buckets, which pick up the ore from the face of the pile, delivering it either into the bins or bin filling cars as may be desired. The cars so loaded are then placed over the proper bins and there unloaded—the bottoms dropped. A more recent plan is that adopted at Neville Island, Mingo Junction, and Youngstown, where a Hulett ore bridge was built by Webster, Camp & Lane, of Akron, Ohio. The clear span is 260 feet, with a cantilever extension of 41 feet commanding the ore bins. The method of handling the ore with this system may be briefly outlined as follows: The ore car, which may be either gondola or

hopper, is placed on the dumping machine; when in position, the car is rotated through an arc sufficient to cause a free flow of the ore, which in passing through the chutes is deflected into four side dumping bridge cars mounted on a transfer car. These bridge cars have a capacity of 17 to 20 tons, and the car dumper will easily handle 15 cars of ore hourly. The transfer car is then moved under the machinery tower of the conveyor bridge, where by means of a cable the bridge cars are pulled up on one of four converging tracks to the through bridge track and automatically dumped at any desired point, either in the stock yard or furnace bins. In taking ore from the stock pile to the bins or bin filling cars two methods may be used, and in both cases the buckets are operated by the motors operating the bridge cars. A second track, suspended below the main track, carries a trolley, to which is attached a scraper bucket holding about 10 tons; about 15 buckets per hour can be taken from the pile to the bin filling cars. In the second method, a two part grapple bucket holding about 12,000 pounds of ore is used; 25 to 30 buckets are handled hourly by this arrangement. As the bucket operates vertically, it has the advantage of working in the center of the ore pile, where trouble from the frost will be less than working on the inside of the pile. The cost of transferring ore from the cars to the stock pile with the Hulett bridge is said to be less than one cent per ton.

The ore now being in stock, the next step is to get it to the furnace. In the case of the larger furnaces the vertical hoist tower carrying its cumbersome charging barrows was found to be a slow and costly method and has been superseded by the skip way or incline. The ore train, handled by a small locomotive running on tracks placed between the ore bins, is made up of special cars, each of which carries a charging scale, on which rests the ore bucket capable of holding 10,000 pounds of ore. These buckets, when properly filled with the required kinds and quantities of ores, are pushed under the incline. The central bucket rod, pendant from which is an iron cone or bell closing the bottom of the bucket, is now grasped by a bifurcated hook hanging from the incline carriage; from this point they are rapidly carried to the fur-

nace top and there quickly emptied by lowering the bell forming the bottom of the bucket. This very ingenious arrangement is in use only at Duquesne; possibly a more typical furnace top is that in use at the Youngstown furnaces. Before considering the top, however, let us first take up the method of assembling the burden. The skip filling car commands the full length of the ore bins. It is a side dumping car electrically operated and carrying its own scales. This car delivers the ore from the bins directly to the skip car, which rests in a water tight tank immediately in front of the car.

The limestone is delivered from the bin directly into the skip car, while the coke is also delivered directly into the skip from the bin. The skip, holding about 15,000 pounds of ore, is now carried to the top of the furnace, where it is discharged into the receiving or supplementary hopper which is designed to hold a skip load. The small bell closing this hopper is now lowered by means of the 14-inch oscillating cylinder actuating a counter-weighted beam; the descending column of ore is evenly distributed around the main furnace hopper, which holds a 30,000 pound ore charge; this bell is operated by the 16-inch cylinder. The bell rod of the small bell is hollow and through it passes the solid rod of the large bell. In operating this arrangement the upper bell is always closed during the period the lower bell is discharging stock into the furnace; the seal so formed prevents the waste of the furnace gases. In the charging apparatus built by the Brown Hoisting Machinery Co., the skip dumps into a central receiving hopper carrying an inclined spout, which delivers the ore at any given point on the periphery of the bell; as successive charges are dumped into this receiving hopper, it is caused to rotate through any desired angle. It is evident that a furnace charged in this manner closely approaches the hand filled furnace so far as facility of controlling stock distribution on the bell is concerned. Skips are operated by steam or electricity; in either case an automatic slowing device is used which causes the skip to come to rest gradually and without shock.

Another interesting part of the equipment of the modern blast furnace is the casting machine. In dealing with the

heavy tonnage involved it was found necessary to have a quicker and more reliable, as well as a cheaper and less laborious, method of handling the iron than that afforded by the old system of casting in pig beds. To meet this demand several well known machines have been devised, one of which, the Uehling, is built by the American Casting Machine Co., at the Edgar Thomson works. The pigs weigh from 110 to 115 pounds, and being free from sand are much more acceptable than the sand laden pigs of our forefathers. Slag machines of the Hawdon type have also been installed in several plants where the local conditions seemed to warrant this particular method of slag disposal. As long as the slag dump affords sufficient room, the ladle car will likely continue as the cheapest and quickest method of disposing of what is still very largely a waste product. In this connection it is interesting to note that several furnace plants, notably the Illinois Steel company, are making a high grade Portland cement from their furnace slag.

Another feature of the modern furnace deserving special mention is the water cooled bosh plate. As late as 1890 we could not point to a single furnace which had produced 250,000 tons during the life of a lining; to-day we have records exceeding 1,000,000 tons. Early experiments with water cooled cast iron plates built into the bosh walls demonstrated the efficiency of this method of preserving bosh walls. These iron blocks were, however, rather difficult to replace when making renewals, and as a result of continued efforts toward improvement along these lines we have to-day several well known forms of bronze or copper bosh plates, which are built into the bosh walls. In the case of the well known Scott plate they are built into the walls with a relieving arch of brick thrown over each plate. In other cases, as with the Gayley, these arches are dispensed with. In more recent practice an iron arch or socket plate which acts as a holder for the water block has been adopted. The larger plates formerly used have given way to a greater number of smaller plates; the total amount of copper in a given furnace is not increased by this arrangement, but a more thoroughly protected bosh is the result. At the tuyere belt these plates

are placed a minimum distance apart (vertically), usually just far enough to allow the proper space for the thickness of the socket plates and the depth of the bosh bands. As we leave this region of intense heat and approach the top of the bosh, the plates are gradually spaced further apart. A circular feed line carrying water at 10 to 30 pounds pressure supplies the legs or manifolds placed at each column. The water is conducted from these manifolds to the lowest row of plates and allowed to ascend through the series, finally discharging into the water trough. Above the mantle plate it is desirable to use a gravity feed instead of pressure. The hearth is protected by a heavy steel jacket cooled by a water spray, or a cast iron jacket built up in sections each of which carries a coil of pipe through which the cooling water circulates. With the increased bosh life it was found necessary to protect the brick work forming the throat of the furnace in order that both top and bottom might die together. In some instances water cooled blocks have been used for this purpose, but this seems a needless refinement, since a series of cast iron plates properly arranged will furnish all needed protection for this portion of the furnace.

The scope of this article will scarcely permit more than a reference to the hot blast stoves of the modern furnace; with these the evolutionary process has been chiefly one affecting size rather than one causing any radical changes in former well known designs of the regenerative type. Some of the recent stoves have been built 21 feet in diameter and 118 feet high.

In the case of the modern blowing engine we find the poppet, slide, and piston valves of the steam cylinder replaced by the Corliss. The modern engines are of the vertical cross-compound condensing type, as illustrated by the Tod engine built for the National Steel company. The diameter for the high pressure cylinder of these engines is 54 inches, that of the low 102 inches, giving a volumetric ratio of 3.57. The air cylinders, which are tandem to and above the steam cylinders, are 108 inches in diameter; the common stroke is 60 inches. At 160 pounds steam pressure and 26 inches vacuum, these engines will develop 5,000 indicated horsepower when running at

45 revolutions, and deliver 57,000 cubic feet of free air per minute at 25 pounds pressure per square inch. The weight of these engines is about 635 tons each. In this connection it is to be regretted that the internal combustion engine, using furnace gases, has not yet found its way into American plants even experimentally. The barbarous practice of developing power by means of the steam boiler continues as the accepted method. From an economic point of view this subject offers a most attractive field, and it is to be hoped that the next epoch in blast furnace practice will record achievements as successful along these lines as those briefly chronicled in this incomplete resume of modern blast furnace practice.

THE FOUNDATIONS OF THE AMERICAN IRON INDUSTRY.

BY ARCHER BROWN.

[Archer Brown, iron expert; born in central New York; educated in Michigan; graduated from Michigan university literary department, 1872; engaged in journalism in Cincinnati for eight years, last five years as managing editor of the Cincinnati Daily Gazette. In 1881, joined William A. Rogers in forming the firm of Rogers, Brown & Co., general pig-iron commission merchants. In 1895, removed to New York City to superintend the eastern and export trade of the firm. 1897-8, spent five months in Europe studying relations of American iron to English and Continental markets. Residence, East Orange, N. J. The firm of Rogers, Brown & Co. handles about one-third of the product of the blast furnaces of the United States that comes to the open market, their sales running about a million and a half tons a year. Mr. Brown's remarkable grasp of the American iron-producing situation lends unusual importance to his review of the field which was written for the Engineering Magazine.]

The development of the iron industry of the United States has been marked with surprises. From complete dependence upon the old world the country has leaped to a pre-eminence so complete that even its rivals believe and tremble. In the great railroad building period 1870-72 England furnished the rails and other materials at prices two or three times above those which are now deemed abnormally high. Then England produced three times as much iron and steel as the United States. Since then Germany has challenged the supremacy of Great Britain, and passed her in a decade of remarkable growth. And yet, in 1902, the United States produced more iron than England, Germany and France combined. If we add to this statement another fact, viz., that even this vast production is not sufficient for home requirements, and that the United States is to-day, in spite of a stiff tariff, the best customer in iron and steel that Europe has, credulity is taxed to the limit.

This unparalleled growth has not been without its backsets. The ups and downs of the trade have been so marked as to call from its chief prophet the expression that iron is either a prince or a pauper. Indeed the vicissitudes have been so great, and the ill starred enterprises so numerous, that capital has always had a peculiar dread of it, and con-

servative investors have counted it a hazardous field. An industry so vast, so episodical, so filled with promise of still further greatness, and so closely linked with the whole fabric of national material progress, naturally comes in for a full measure of discussion.

What will be its future? Are the wonderful natural resources on which it is built inexhaustible? Is the support of a protective tariff longer needed or desirable? Can American manufacturers hope for a world trade and continue paying to labor double the rates paid by their rivals? Is the enormous home consumption a stable or a temporary factor? Will the consolidation of mines, furnaces, mills, and carrying lines, into great corporations with huge aggregations of capital, help or hinder the broad development of the industry? Can the facilities for the cheap assembling of raw materials, which are the wonder of other nations, be further improved? There is material in these and like inquiries for ample and interesting study.

It is first of all in the vast natural resources of the United States that the industry finds its sure foundation. The basis of all iron and steel making is reliable coking coal and iron ores suited to the Bessemer or the basic process of producing steel. The Connellsville district in Western Pennsylvania carries the largest known seam (9 feet) of high grade coking coal. But the district is distinctly limited, and at present rate of mining, will be exhausted within a generation. Nature, however, was lavish in providing reserves. The developments of the past ten years among the vast bituminous coal regions of West Virginia, southwestern Virginia, southeastern Kentucky, and eastern Tennessee, have revealed deposits of high grade coking coal that would seem to be ample to supply the blast furnaces of the world for centuries to come. It is only a question of building railroads, opening mines, and constructing coke ovens. The far sighted action of the United States Steel corporation in acquiring and developing a great tract of this coal in the Pocahontas field in order to conserve its Connellsville supply is the most important step yet taken in shifting the base of fuel supply.

Not all good bituminous coal will make coke. Indeed, in all the great coal fields of Ohio, Indiana, Illinois, Missouri, and important coal sections of Tennessee and Kentucky, there has not been found an acre of coking coal. Draw a circle around the Connellsville section in Pennsylvania including the so-called Mountain operations adjacent on the east; another around the section where Virginia, West Virginia, Kentucky and Tennessee meet; another around the Warrior coal field in Alabama, and a fourth around a newly developed district in Colorado and Utah, and you have all the known sources of fuel supply for iron and steel making in the United States. It is true that anthracite coal is still used in connection with coke, in the blast furnaces of eastern Pennsylvania, but it is a small and diminishing factor.

Though the growth of coke production has been very rapid in the past few years, it has not kept pace with the demand, and the remarkable year of 1902 witnessed the banking of furnaces for days and weeks because of short fuel supply. As late as 1880 the total coke production was only 3,338,300 tons. In 1890 it had grown to 11,508,021 tons, and in 1901 it reached 21,795,883 tons, of which probably 85 per cent was used in the smelting of iron ores. Of this total, Pennsylvania produced two thirds, West Virginia a tenth, and Alabama, Virginia, and Colorado the remainder. The government records show the cost to have been $1.28 per ton in Pennsylvania, $1.88 in Alabama, $1.15 in Colorado, and $1.11 in West Virginia. No other coke in the world approximates the cheapness of cost of the great producing centers in Pennsylvania and West Virginia.

Turning to the other bases of iron and steel manufacture —abundant, suitable, and cheap ores—the foundation seems to be equally secure. There is iron ore in thirty one states of the union. Very many of the deposits, however, are unavailable for one or another cause. Thousands of owners of iron lands in Virginia, Tennessee, Alabama, and Georgia, in the south, and in Illinois, Ohio, Wisconsin, and even Pennsylvania, in the north, have had their dreams of wealth dispelled by finding that the ores were too lean, too high in phosphorus or titanic acid or some other injurious element, or

were too expensive to mine profitably in competition with the cheaply won deposits in the Lake Superior districts or in the southern states. Even the first miners on the Mesabi, the richest of all the upper lake ranges, abandoned their machinery and gave back their lands to the state because the ores were too low in iron to stand long shipment. These pioneers were too far south and west.

There are practically but two processes of making steel in the United States—the Bessemer and the basic open hearth. The former is based on the low phosphorus ores of the Lake Superior districts, and until the past five years, it had the right of way. More recently, however, the basic process has assumed importance, and its growth has been far more rapid than that of its older rival. Indeed, it may almost be said that Bessemer steel making reached its climax several years ago, and that the recent wonderful growth in steel making has all been in the basic form. This process has the advantage of using the higher phosphorus ores that are found in many states. The standard specification of basic pig is phosphorus 1 per cent or under; silicon 1 per cent or under; and sulphur 0.05 or under, manganese between 0.05 and 2 per cent, the higher preferred.

The supply of low phosphorus ores for making Bessemer steel was apparently nearer its limitations ten years ago than it is to-day. The so-called old range ores were being mined out at a rate that caused apprehension, and new discoveries were few. The opening of the Mesabi district in Minnesota however, in the decade from 1890 to 1900, changed the situation. The Mesabi ores, usually running rich in metallic iron and very low in phosphorus, proved of almost unlimited extent as exploration work went on. Lying near the surface, in great beds from which the earth was easily stripped off, open mining with steam shovels was possible, bringing cost to the lowest point ever reached in the world. Hundreds of thousands of tons have been put on cars at 25 to 30 cents a ton. In Alabama, where the next cheapest mining is done on a large scale, the average cost of putting the red ores on cars is probably 60 cents a ton. But the Alabama ore carries less than 40 per cent iron, against the Mesabi 60 to 65

per cent. These rich beds could be only partially utilized at
first, because of the extremely fine or powder like condition
of the ores making it difficult to prevent the strong blast of
the furnace from forcing them through the flues or out of the
top.   Engineering skill, however, has largely overcome this
difficulty, and by mixing a small percentage of the old range
ores, good results are reached.   It might be remarked in
passing, that it is in the almost complete ownership of these
old range Bessemer ores, essential for mixing, that the United
States Steel Corporation comes nearest to control of the
situation.

The duration of the supply of Lake Superior ores can
only be conjectured.   Since the great revival in iron in 1899,
exploration work has been carried forward with great energy,
and it can safely be said that new sources of supply are opened
faster than old ones are worked out.   Close to 25,000,000
tons per annum, however, are now being brought down the
lakes and this colossal tonnage cannot be taken from the
ground each year without leaving some tremendous gaps,
which nature at present is not engaged in supplying.   Some
new and considerable deposits have been found in Canada,
and the north shore of Lake Superior is known to be rich
in iron, although so far as developed, sulphur is found to be
present in troublesome quantities.

Basic open hearth steel making would seem to be secure
for all time on account of the wide range of ores which can
be utilized.   The non-Bessemer Lake Superior ores are now
most extensively used; next comes the high manganiferous
ores of Virginia, and lastly the cheaply mined red ores of
the Birmingham district in Alabama.   In the latter section
there has not been the rapid development of basic steel making
that has been expected, owing to a variety of causes.   In
the building of the past few years, the great expansion in
open hearth plants has been in eastern Pennsylvania and the
central western states.   The magnetite and hematite deposits
of New Jersey, partially neglected a few years ago, are found
to be peculiarly adapted to the making of high grade steel,
and a new and important future is opened for these proper-
ties.   It is not generally known, perhaps, that one of the

largest and most costly blast furnace plants yet constructed in the United States has gone into operation recently in New Jersey, within two hours ride of New York, and in a district supposed to have been abandoned as an iron making center.

Before leaving the subject of iron ores, it may be mentioned that very extensive deposits have been explored in sections of the country too remote from the great manufacturing centers to be available for commerce for many years to come. Wyoming, Utah, Washington, and even California, have mountains of high grade ores, needing only railroads, furnaces, mills, foundries, and an adequate market for the products. All of these will come in time. Texas also has its rich beds of both Bessemer and non-Bessemer ores, but the absence of coking coal and the remoteness of consuming centers will make the development slow. Mexico likewise is rich in ores, but so poor in fuel that for a long time to come the United States and other countries will have to supply the finished iron needed by the sister republic.

The most important deposits of iron ore outside the limits of the United States, which may either be drawn upon for supplying American furnaces or may appear in finished form to compete with the United States, are in Nova Scotia, Cuba, Venezuela, and Spain. Porto Rico, also has extensive Bessemer deposits. The extensive works lately completed at Cape Breton are now sending about a thousand tons a day to eastern American seaports, about equally divided in form between pig iron and steel billets. The Cuban ores have been used for twenty years as an important source of supply for the leading eastern steel works, but the quantity has increased but little, although energy and capital have been expended liberally in developing what seemed promising properties.

The tariff long ago ceased to be a question of vital import to the American iron industry. It needs no argument to prove that, but for the protection afforded by the tariff in the two or three decades following the war, the development of the great resources of the country would have been retarded indefinitely, to the immense advantage of England and Germany. But that period has passed. The infant is a giant. Does it follow that the tariff wall should now be

taken down or lowered? The answer varies greatly, according to the point of view, or the school of economic belief of the individual. It is probably within the bounds to say that the attitude of most manufacturers is one of indifference, except as tariff changes might injuriously affect the general business situation, now prosperous to a degree never before witnessed in the United States or any other country. A defender of the protection system has only to point to the unexampled activity of the United States, while her great free trade rival is languishing in business depression, to give his answer. The average manufacturer, untrammeled with theories, and seeking only further extension and greater profits in his own business, and with a vivid recollection of the paralyzing effect upon trade of efforts at tariff revision in the past, says let well enough alone. The student sees inequalities and inconsistencies that call loudly for correction. The alarmist discovers giant trusts fattening upon the protection given them at the public expense. The western farmer would like to get his barbed wire lower. The railroad president wants to buy his steel rails at the price afforded by English and German labor. The eastern merchant or structural mill could often buy its billets from abroad cheaper than at home but for the tariff. The great implement and tool manufacturers of the west, with expanding export trade, want reciprocal arrangements with France and other continental countries, and are justly bitter towards the small and highly protected industries of cheap jewelry, knit goods, and the like in the eastern states which have succeeded in blocking the reciprocity treaties in the senate. And so on through the category of varying and conflicting interests.

As to the prospect for a world trade in American iron and steel products, it must be admitted that a few years have wrought a great change, and not in the direction of progress. In 1899 and 1900 American exports of rails, billets, wire, ship plates, and even of pig iron, were on a scale that struck terror to European makers. The United States carried its products to the very centers of production in Great Britain and Germany, underselling them at their doors. Now it is sending abroad nothing but agricultural machinery, machine

tools, and sundry highly finished specialties in which American skill finds particular expression. English and German makers have no sooner pulled themselves together and reduced costs to meet the dreaded American competition, than America has withdrawn from the field. Not only that, but she has astonished them by becoming their largest and best customer, permitting them to ride over the tariff wall with three to five shiploads a day of pig iron, billets, structural shapes, plates, etc. What has made this great change? The revival of trade and industry at home. At the height of phenomental exports, home consumption was still 95 per cent of the American make. Now it is 105 per cent. The home market is, after all, the overshadowing issue. The United States will deal again with the trade of the world when production once more exceeds consumption.

It is too early yet to measure with any degree of accuracy the influence of the great consolidations upon the future of the American iron and steel industry. Two or three things, however, seem pretty clearly established—and these are contrary to popular notion. The first is that, in the larger lines, there is not, and can not be, any monopoly. Competition will be comparatively free. The smaller manufacturers will multiply. If the big consolidations flourish, they will fatten. Their supplies can not be shut off. They can use the same materials and processes as their great rivals. Their management will be often of the same high order, for it will come from the men who have created and own their own business. The small independent manufacturer is seldom over capitalized, seldom mortgaged, and with light fixed charges, he will have a flexibility in the day of trial which will in a large degree offset the powerful advantages possessed by his huge rival in the ownership of raw materials, carrying facilities, the greatest plants, and unlimited working capital. Consolidations will never eliminate competition in the United States.

Another result of the great consolidations, already sufficiently apparent, is the steadying effect upon values. The violent fluctuations of the past, with their disastrous consequences upon all forms of industry, are not likely to recur.

The action of the United States Steel corporation in holding prices within bounds during the stress of excessive demand has no doubt had an influence in prolonging the period of activity. Other makers have seen the wisdom of the policy and, to some extent, adopted it. The real test will come, of course, when demand slackens, and there is not business enough to go around. A conservative policy pursued then by leading makers will quickly adjust supply to demand. The radical one, which has usually been followed in the past, of filling the big mills with work without regard to prices, would provoke a war which would of necessity be hardest on those with the greatest relative fixed charges and outstanding securities. It is safe to assume that, with power centered in fewer and stronger hands than ever before, better counsels would prevail.

There is no more popular belief with respect to the trusts than that they are able to force a higher level of prices at home by selling their surplus abroad at greatly reduced prices. Every man connected with the manufacture of iron and steel knows how complete is this fallacy so far as his own products are concerned. As a matter of fact, for years past the makers of American machinery and other products of iron and steel have, in times of depression at home, realized their best prices in the export business.

The question, so often raised, as to how long the present period of great activity and high prices can last will be answered by different authorities very much according to mental habit and temperament. The conservative reasons from past experience that booms are short lived; that we have usually had five years of declining to two years of advancing prices; that we must before long pay the penalty of the great increase of production witnessed during recent years; that over capitalization of companies and speculative trading can have but one end, etc. The man of optimistic views sees before us a period of national development, and of material progress throughout the world, compared with which even the great achievements of the past are tame. He reasons that iron and steel lie at the very foundation of such progress, and that it is the destiny of the United States to furnish a

steadily increasing proportion of the world's requirements. He thinks the past eight years, with its creation of wealth, its payment of debts, its settlement of financial questions, its uplift in the spirit and ambition of the people, has brought in a new era, and that it is narrow and fallacious to try to square the conditions of to-day with those which prevailed in the years of panic and turmoil.

THE IRON INDUSTRY IN THE UNITED STATES.

BY F. W. TAUSSIG.

[Frank W. Taussig, professor of political economy, Harvard university; educated at Harvard university; he is one of the foremost economists in the world, and is especially known as an authority on the tariff, currency, wages and capital; for several years he has been editor of the Quarterly Journal of Economics, by special arrangement with which periodical the following article is published. Author: Tariff History of the United States, Silver Situation in the United States, Wages and Capital, etc.]

The growth of the iron industry in the United States during the last thirty five years has been so extraordinary, and has been attended by changes so striking, as to make the mere chronicle an instructive chapter in economic history.

Thirty five years ago Great Britain was still the world's commanding producer of iron and steel. Notwithstanding half a century or more of almost continuous protection, the United States held but a distant second place. The output of pig iron in the old country in 1870 was very nearly six millions of tons: that in the new country was but little over a million and a half. But between 1860 and 1870 the product in the United States had doubled,—a geometrical progression, which, if maintained, must soon cause all rivals to be distanced. It is much easier, however, to double a small number or a small output than a large one. Yet in this case the unexpected happened: for three decades the geometrical progression was maintained in the output of pig iron in the United States. The product of 1870 had been double that of 1860, 1880 doubled 1870, and 1890 again doubled 1880. The iron industry of Great Britain held its own, and, indeed, between 1870 and 1880 made a notable advance; but it could not match the astounding pace of its young rival. In 1890 the United States turned out more than nine millions tons of pig iron, for the first time passing Great Britain, and displacing that country suddenly as the leading producer.

This enormous increase, however, has been by no means evenly distributed over the United States. Within the country a revolution has taken place, which is part and parcel

of the changed relation to other countries, and which must be followed before the latter can be understood.

The first great impulse to the production of crude iron on a large scale came in the United States with the successful use of anthracite coal as fuel. During the twenty years preceding the civil war (1840–60) the site of the industry and its growth were governed by this fuel. Hence eastern Pennsylvania was the main producing district. For some time after the close of the civil war this dominant position was maintained. In 1872, when the systematic collection of detailed statistics began, out of a total production of 2,500,-000 tons, one half was smelted with anthracite coal, a third with bituminous coal or coke, the remainder with wood (charcoal). The use of soft coal, which had begun before 1860, became rapidly greater. In 1875 for the first time its output exceeded that of the rival eastern fuel, and since that date the huge advance in the iron product of the United States has been dependent on the use of coke.

This change is easy of explanation. It is the inevitable result of the greater plenty and effectiveness of coke; and it has been powerfully promoted by the rapid development of the United States west of the Appalachian chain, and the nearness of the coke region to this growing market.

Pittsburg, long ago seen to be destined to become a great iron center, is situated in the heart of the region where coking coal is plentiful. To this point the iron industry has converged, attracted first by cheap fuel, and soon by other geographical advantages of the region—its easy access to the growing western country, and the added opportunities of securing superabundant quantities of the best ore. Pennsylvania has remained the greatest iron producing state in the union; but since 1880 it has been western Pennsylvania, and no longer eastern, which has secured to the state its leading position.

The westward movement has been no less affected by the distribution of the ore supply; and the effect of this in turn has rested on the revolution wrought in the iron trade by the Bessemer process.

The first inventions which made plentiful the iron indispensable for all our material civilization were Cort's processes for puddling and rolling. In the decade 1860–70 the process devised by Sir Henry Bessemer, to which his name attaches, began a revolution in the iron trade. Bessemer steel to-day has displaced puddled iron in most of its uses. Not only this, the cheap and abundant supply, besides filling needs previously existing, has opened vistas for new plant, machinery, durable instruments of production of all sorts.

But the Bessemer process depends for its availability on special kinds of ore and pig iron—such as are well nigh free from sulphur and especially from phosphorus. But the greater part of the eastern ores were too highly charged with phosphorus, or for other reasons unavailable. The Lake Superior iron region, long known to explorers and geologists, suddenly sprang into commanding place. Here were abundant and superabundant supplies of rich and properly constituted ore. These and the equally abundant coal of Pennsylvania were brought together, the iron made from them was converted into steel by the Bessemer process; and thus only became possible the astounding growth in the production of iron and steel in the United States.

The iron mines of the Lake Superior region stretch in widely separated fields along the lake, from the middle of its southern shore to its extreme northwestern end. In all these fields the ore has been secured by what we commonly think of as mining,—by digging into the bowels of the earth, and bringing the material up from a greater or less depth. But in very recent years the latest and now the most important of the fields has given opportunity for the simplest and cheapest form of mining: great bodies of ore are lying close under the ground, and, when once the surface glacial drift has been removed, obtainable by simply digging and shovelling, as from a clay pit.

From the shipping port the ore is carried eastward by water to meet the coal,—the coal being coked at the mines, and in that form made best available for smelting purposes. Some of the ore goes down Lake Michigan to Chicago, where it meets the coal from Pennsylvania about half way. Some

of it goes farther, through Lakes Huron and Erie, and meets the coal at Toledo, Ashtabula, Cleveland, and other ports on Lake Erie. The largest part is unloaded from the vessels at lake ports, and carried by rail to the heart of the Pittsburg coal district, there to be smelted by the coal on its own ground. No small amount goes even beyond,—to the eastward in Pennsylvania, beyond the Pittsburg district, even into New Jersey and New York, almost to the seaboard itself. Hence the cities of Erie and Buffalo have become important ore receiving ports on Lake Erie.

The iron producing region which depends on the Lake Superior ores thus stretches over a wide district, the extreme ends being separated more than a thousand miles. Close by the iron mines are a number of charcoal using furnaces in Wisconsin and Michigan. The still unexhausted forests of these states supply this fuel in abundance; and charcoal iron, though long supplanted for most uses by the coke smelted rival, has qualities which enable a limited supply to find a market, even at a relatively high price. Next in order come Chicago and some neighboring cities, among which Milwaukee and Joliet are the most notable. It is one of the surprises of American industry that iron manufacturing on a huge scale should be undertaken at such points, distant alike from ore and from coal, and having no natural advantages whatever. The coke is moved hundreds of miles by rail from Pennsylvania and meets the ore which has travelled no less a distance from Lake Superior. Ease of access to the western market gives these sites an advantage, or at least goes to offset the disadvantage of the longer railway haul of the fuel. Other iron producing points of the same sort are scattered along Lake Erie. At each of the ports of Toledo, Lorain, Ashtabula, Erie, Buffalo, especially Cleveland, ore is smelted, and iron and steel making is carried on.

But the coal region itself—western Pennsylvania and the adjacent parts of Ohio—remain the heart and center of the iron industry. Hither most of the ore is carried; and here the operations of smelting, converting into steel, fashioning the steel into rails, bridges, plates, wire, nails, structural forms for building, are performed on the greatest scale.

Whether the ore goes to the coal or the coal meets the ore half way, one or both must travel a long journey, by land as well as by water. One or both must be laden and unladen several times. Fifty years ago, even twenty years ago, it would have seemed well nigh impossible to accomplish this on a great scale and with great cheapness. One of the most sagacious of American students of economics, Albert Gallatin, early predicted that the coal area of western Pennsylvania would become the foundation of a great iron industry, and that only with its development would the American iron manufacture attain a large independent growth. But he could not dream that his prophecy would be fulfilled by the utilization of ores distant fifteen hundred miles from the seaboard, transported from a region which was in his day, and remained for half a century after his day, an unexplored wilderness.

The history of the American iron trade in the last thirty five years is thus in no small part a history of transportation. The cheap carriage of the ore and coal has been the indispensable conditions of the smelting of the one by the other. And, clearly, this factor has not been peculiar to the iron industry. The perfecting of transportation has been almost the most remarkable of the mechanical triumphs of the United States. In the carriage of iron ore and of coal the methods of railway transportation developed under the stress of eager competition have been utilized to the utmost; and the same is true of the transfer from rail to ship and from ship to rail again, of the carriage in the ship itself, and of the handling of accumulated piles of the two materials.

Still another factor has been at work in the iron trade, as it has in other great industries,—the march of production to a greater and greater scale, and the combination of connected industries into great single managed systems. Nothing is more wonderful in the industrial history of the past generation than the new vista opened as to the possibilities of organization. The splitting up among different individuals and separate establishments of the successive steps in a complicated industry—those of the mining, carrying, smelting, rolling, fashioning of iron—was supposed to be due to the limitations of human brain and energy: the management of

them all was beyond the physical and nervous capacity of any one man or of any small group of associates. But the range of single management, the size of the unit, have enlarged prodigiously.

The iron trade has shown as markedly as any of the great industries the signs and effects of these new conditions. Not only has the size of individual establishments grown—this is a phenomenon of long standing—but the number of industries united in one organization has rapidly enlarged. Iron mines, coke ovens, railways, steamers, docks, smelting works, converting works, rolling mills, steel works, machine shops—these have been combined into one imposing complex.

While the Lake Superior ores have been by far the most important source of supply for the iron industry, a large contribution has come from another source, also—from the southern states.

In the region where the states of Tennessee, Alabama, and Georgia adjoin, the conditions once thought indispensable for a flourishing iron industry exist in perfection. Here are great deposits of ore, easy of working; and close by them great deposits of coking coal, no less easily worked. Before the civil war, these natural advantages were not utilized; the régime of slavery and the lack of means of transportation prevented any resort to them. But with the quickening of the industrial life of the south, when once the civil war and the trying days of reconstruction were passed, the mineral resources of this region were developed on a rapidly enlarging scale. Alabama, where the best deposits of coal occur, became a great iron producing state; here again, though for a less distance and on a smaller scale, the ore made its journey to the coal. The large supply of labor at low wages has contributed to the easy and profitable utilization of this source of supply. The free negro has turned miner, and has proved not only a docile laborer, but also—paid, as miners are, according to the tonnage brought to the pit's mouth—on the whole, an efficient one. The favorable natural conditions, when once unlocked by the régime of freedom and the means of transportation that came with it, doubtless constitute the main basis for the growth of the Alabama iron industry.

The southern ore contains phosphorus in too large amounts to make it available for the Bessemer process; and this has given it a place somewhat apart in the iron industry of the country. The iron made from it has not competed with that from the Lake Superior ore, and has been used chiefly for general foundry purposes. Marketed at a very low price, the increasing supplies have made their way to places further and further removed. Pittsburg itself soon used Alabama iron for foundry purposes; the western states and the eastern alike were supplied; in New England it displaced Scotch pig, previously imported in considerable quantity; and, finally, it began to be exported to England itself. These exports are probably not of importance in the permanent current of trade; the iron has gone out chiefly in a period of unusually depressed prices, and even at this time only as ballast for cotton ships. Beyond this strictly limited movement we shall probably see the export of iron from the United States, not in its crude form, but in much more advanced stages.

Before we close this review of the forces which have been at work in the iron industry, some other aspects of the subject deserve brief attention. Here, as elsewhere, the labor situation and the trade union movement have had their influence. But the power of the labor unions among the iron workers has been less in the United States than in Great Britain; and this fact has been of no small consequence. It is true that the Amalgamated association of iron and steel workers has long been a firm and powerful organization, modelled on the British unions and strong in its bargaining with the employers. But some of the large iron and steel establishments have been non-union; and their competition, as well as the example they set of a possible cutting loose from the organized laborers, imposed a strong check on the union's control of the conditions of employment. The Carnegie company, thus cut loose from the union, as a consequence of the great strike—fairly a pitched battle—at the Homestead works in 1892. The consequence has been that the American iron and steel master has felt more free than his British rival to push on with new processes, to remodel his organization, to readjust his labor force.

AMERICA'S PRIMACY IN IRON AND STEEL PRODUCTION.

BY JOHN FRANKLIN CROWELL.

[John Franklin Crowell, expert agent of the United States industrial commission and expert on internal commerce; born Nov. 1, 1857, at York, Pa.; was graduated from Yale in 1883; he was principal of Schuylkill seminary, Fredericksburg, Pa., in 1883-4 and 1886-87, in 1887 becoming president of Trinity college, North Carolina, remaining there until 1894; in 1900 he accepted his present government position, and in 1903 was the lecturer on international trade and commercial geography at the Columbian university; he is the author of The True Function of the American College, The Iron and Steel Trade in the United States, in addition to economic and social studies published in the reviews.]

When Abram S. Hewett went to England to receive the Bessemer medal in honor of his contributions to the art of iron and steel making, he took occasion to point out some of the effects produced upon English social institutions by Bessemer's renowned discovery. At that time, it had hardly entered into the minds of men that a still more revolutionary discovery was dawning upon western society, the apprehension of the fact that the primacy among modern nations in the production of iron and steel was rapidly and permanently passing to the United States. Primacy in production has changed the relation of every other nation to the world market. The progress of the United States from being a supplier for domestic consumption to the role of a competitor for contracts everywhere, has forced the whole question of the industrial and commerical strength of nations into the arena of international debate, in which European nations, without exception, have put themselves upon the defensive.

The chief reason for this apprehensive feeling toward the United States is to be sought in the radical, yet inevitable, change in our relation to the world market. Within the last few years, apparently, the United States has ceased to be merely a purveyor of raw materials, and has assumed the rank of a world power. As long as our breadstuffs and provisions ministered to the material needs of Europe, there was no uneasiness. As long as our raw cotton clothed our neighbors across the Atlantic and their customers, nobody thought of economic alliances against the United States. But the mo-

ment it is seen that we have become masters in making and using iron and steel in both peace and war, and that, as a nation of over eighty millions, we are one in the work we have to do in the world's progress, then, naturally, something akin to a panic seizes upon the minds of those who have so long been accustomed to act without taking the United States into account as an industrial and commercial power.

The present position of the United States in making and marketing her iron and steel is one of peculiar strength, even among nations that are especially prominent in this branch of production. For that reason, no other phase of our national development has been more carefully studied by competent observers from abroad. There seems to be on their part a quite unanimous agreement that our ascendency is due to three elements of power: (1) The presence of high grade iron ores and coking coal in unequaled abundance. (2) Superiority in industrial organization, involving all the economies of production and distribution, especially in mining the raw materials, in handling them on a large scale from mine to furnace, in standardizing steel forms and parts of machinery, and in the mechanical equipment and co-ordination of manufacturing establishments so as to enable each one to specialize with a minimum of waste in a given line of production. (3) The remaining element of strength in the position of the United States, in its relation to the world market, lies in its having a better home market than any other nation. Nowhere is there another group of people, equal in numbers and under the same economic system, that can compare with the United States as a consumer of iron and steel. We have for many years been the world's leading builders of railroads; in the quantity of steel consumed, this country has been foremost in bridge building, and the same may be said of the use of structural steel in the erection of high buildings. Only in ship building have we hitherto held a secondary position. Nowhere else do iron and steel enter so largely into the manufacture of agricultural implements.

As regards volume of production of iron ore, the first position in the world belongs to the United States. This fact, taken in connection with our similar rank in coal production,

means that this country has reached a position of self sufficiency unlike that of her principal competitors—Great Britain and Germany—both of whom have been obliged to rely to a considerable extent on importations of either iron ore or coal. This has given a greater freedom to the American iron industry in its effort to adjust itself to the conditions of maximum economy in the accumulation of raw materials and in the distribution of products.   Hence the general tendency of iron and steel production to seek in the north the shores of the lower lakes where the lake ores can be easily distributed, or to concentrate in the neighborhood of Birmingham in the south, where the raw materials are most economically placed by nature.

There are no international boundaries to cross, and production and distribution have consequently been organized on a scale that admits of the most economical location of plants.   In obedience to this principle of progress by relocation, the pig iron industry—the basic industry of iron and steel manufactures—has developed through three distinct stages in the United States: (1) The charcoal era (to 1854, say) when every state had its own small furnaces and foundries.   (2) The anthracite era, when the country's iron industries flourished mainly in the valleys of the Lehigh, the Schuylkill, and the Susquehanna, from the hard coal regions to the sea (1854–1875).   (3) The bituminous coal and coke era (1875 to date), in which the center of pig iron production passed beyond the Alleghenies, and thence spread westward and southward with the growth of national consumption.

The production of pig iron serves possibly better than that of any other product as an index to the comparative success with which the leading countries have utilized their raw materials.

The world's six greatest producers of pig iron are, in quantitative order, the United States, Great Britain, Germany, Russia, France, and Belgium.   The primacy of the United States cannot be fully understood without reference to the way in which this industry has made use of inventions for the utilization of iron ores.   In the manufacture of pig iron to be made into steel, two principal methods are gen-

WORLD'S PRODUCTION OF COAL
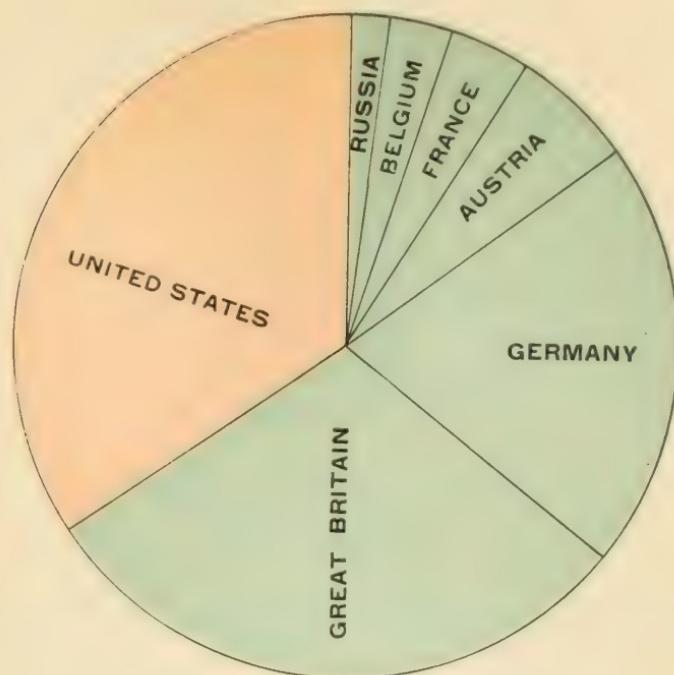
WORLD'S PRODUCTION OF IRON
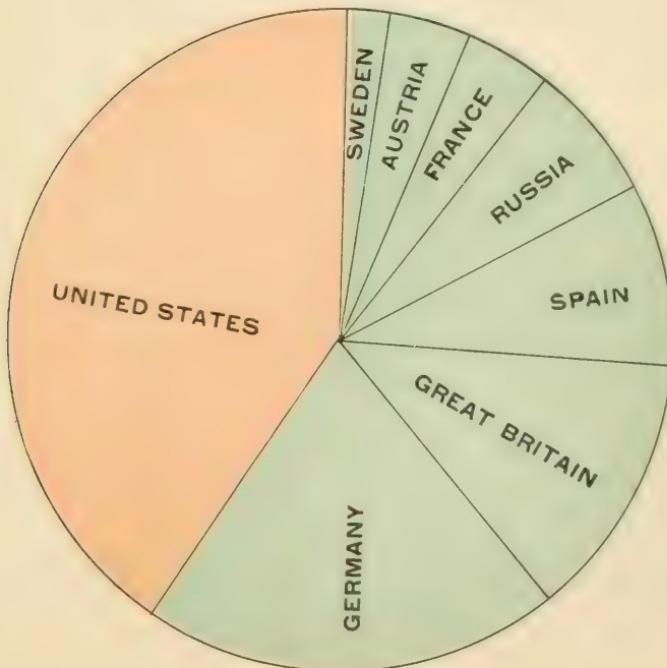
erally followed, the Bessemer process and the open hearth process. The use of either is determined by the quality of the ore. The Bessemer process requires a high grade of ore, one comparatively free from phosphorus, while the open hearth process is adapted to the use of low grade ores. Consequently, the abundance of high grade or Bessemer ores, found at the head of the Great Lakes, made the United States the home of the Bessemer process, whereas other countries having to use low grade ores have had to employ the open hearth process, or some other process more expensive than the Bessemer. Until recently, at any rate, the Bessemer process seems to have been the only one that admitted of production on the extensive scale achieved by the United States steel producers.

Both Great Britain and Germany have had to resort to the use of the more expensive methods of steel production, owing to the absence of ores in sufficient quantity, and of the requisite quality, to make possible the employment of the most economical method of manufacture. This handicap has been much in favor of the United States. How long it will last is a matter of speculation; but it is apparent from the progress made in the open hearth method, even in the United States, that strenuous efforts are being put forth to perfect processes of production in which lower grade ores than the Bessemer process requires may be profitably employed in competition with Bessemer steel.

The supply of rich ores of too high phosphoric content for Bessemerizing is so abundant throughout the United States that we only await the more perfect adaptation of some such process as the Talbot continuous process of steel production, or such a method of treating low grade ores by concentration as that which Edison has really brought to the verge of success, to open a new era in the evolution of the iron and steel industry in this country.

There is no more instructive chapter in the history of the evolution of the iron industry than that which presents the facts bearing on the conversion of the United States from an iron consuming to a steel consuming country. If the proportion of pig iron converted into steel is an index to the

metallurgical development of a country, then the United
States again ranks first among nations.   France, for example,
produces only twice as much manufactured steel as iron.   Ger-
many makes five times as much steel as iron.   Generally the
use of steel is on the increase as a substitute for iron, owing to
its cheapness, efficiency, and durability.

The world's annual production of pig iron, which forms
the basis of manufactured iron and steel, is 40,000,000 tons
in round numbers.   Fully 27,000,000 tons of this is made into
steel products, and nearly 40 per cent of this steel is credited
to the United States.

The position of the United States in its trade relations
with other countries has undergone no more radical change
during the past decade than as importer and exporter of iron
and steel.   At the beginning of the decade, our imports were
valued at nearly twice the sum of our exports of these com-
modities.   Now our exports are more than five times the
value of our imports of iron and steel.   This turning of
the tide in the American iron and steel trade toward Europe,
Africa, Asia, and Australasia marks the end of an old, and the
beginning of a new, régime, not only in our relations with our
competitors, but also in the economic position of this industry
at home.   The general problem before the American iron and
steel industry is that of developing foreign markets systematic-
ally on the basis of maintaining the prices of its products at a
fairly, if not indeed a highly, profitable level.   But the great
avenues of domestic demand, such as that of steel rails, are
no longer to be relied upon to take the major portion of the
product in question.   The industry has outgrown the capacity
of the home market.   Both industrially and commercially this
industry is so completely organized that it must enlarge its
markets to save itself.   In this situation, it has three distinct
lines of policy open before it: (1) It can follow the two price
policy of getting all it can out of the home market, and having
irregular recourse to the foreign market at a price far enough
below the domestic price to carry off its surplus products as
they happen to accumulate.   If it relies on the elements of
monopoly in its present position, it will continue to do this.
But this policy has already become the bane of our export

business, and no far seeing management of an industry so highly organized and so admirably equipped as this one is with men of commercial and financial ability, would fold its opportunity away in the napkin only when it could not help itself. (2) If this policy is a thing of the past, then we may adopt the plan of developing the home market by lowering prices and by seeking new avenues of consumption in the domestic demand, by the substitution of iron and steel for wood and other materials, as has been done with marked success in steel car manufacture and in the construction of bridges, office buildings, machinery, implements, tools, etc.—all of which are in increasing demand with the broadening basis of the internal development of our national life. But here, again, the rate of this expansion of internal demand is far below the rate at which the volume of iron and steel production increases on the present scale of organization. (3) Consequently, there is left for us only one other policy—that of cultivating the world market against all competitors, systematically and without stint. With the capital, the mechanical and business capacity, and the vast natural resources at its command, under its existing organization the American iron and steel industry has no alternative between vegetating in fatness at home and fearlessly meeting its rivals in the world market.

The entrance of the United States upon such a career of commercial aggression would not, however, be without its risks and drawbacks. Four consequences seem to be equally probable as the result of this change in the relation of this country to the world market:

1. The steady but certain advance of European tariffs all along the line against the United States. A European concert is politically impossible, but individually it is inevitable, as a means of self preservation. France and Russia represent the type of economic policy that our own expansion is bound to provoke into greater or less permanency, especially on the continent.

2. The formation of an imperial customs union on the part of Great Britain and her colonies, as Canada proposed, on the basis of freedom of trade within this fiscal group, but

with protection for revenue and mutual preservation as the basis of relations with the outside world. Great Britain alone may hardly take the lead in returning to the protection policy (though the export tax on coal is virtually a concession in that direction), but she will welcome with a deep sense of relief the formation of a protective cordon of colonies as the corner stones of imperial solidarity.

3. The lowering of tariffs on the part of the United States, not only for the purpose of recognizing the right of the domestic consumer to share in the reduced cost of iron and steel production, but for the equally important purpose of admitting imports more freely, in order that foreigners may buy more freely of our exports. Only to a very limited extent will foreign nations give up their gold to settle trade balances; beyond that they must sell goods to us to buy goods from us. Our own trade expansion will thus force our tariffs downward.

4. As a consequence of higher tariffs against us on the continent, and of the British imperial tariff union, limiting our sphere of expansion in these directions, the keenest competition will occur in the tropics and in the far east. Here the British and German mercantile marine will readily demonstrate their present superiority in that arm of commerical efficiency, as compared with the United States. Hence the advent of the United States as a mercantile sea power of the first rank is one of the immediate consequences of our rise to primacy in the world's production of iron and steel. As for our ability to make steel ships, the shipyards of the New England coast, of the Delaware, the Chesapeake, of San Francisco bay, and Puget sound can speak for themselves; they only await a greater volume of demand to rival both Great Britain and Germany in this respect. Already our shipyards are the best equipped with electrical and other labor saving devices.

Do these developments make for peace, or tend to war? That depends on how deep we look. On the surface, trade is war; at heart, however, commerce ministers more and more to the fund of fellowship among nations. America, Great Britain, and Germany, being more nearly matched in industrial and commercial equipment than ever before, these three great competitors of the same racial household will have reached an

enduring basis of international peace. Each has yet to learn more fully what the characteristic features of strength are in the position of its rivals in the world's iron and steel trade. The restless demand for improved methods and machines, which intelligent workmen have readily applied to this industry, has put America where she is—the foremost producer of iron and steel. The technological training of men and masters in ironworking processes has enabled Germany to rise as the worthy competitor of both Great Britain and the United States. No other single feature of German development has done so much to bring her trade to the front rank of excellence and value. The position of Great Britain is what it is to-day and what it was in the past because of her commercial genius. Prolonged leadership in trade has, however, made her lax and caused her to lose the art of quick adaptation to changed conditions of competition. In the lessons which each of these powers is seeking to learn from the others, these three characteristic factors contain the secrets of the century's progress in the iron and steel trade—the invention of machinery and methods, the education of the worker, and the cultivation of the consumer. Permanent peace and prosperity lie along these paths.

NATIONAL IDEALS IN IRON TRADE DEVELOPMENT.

BY H. J. SKELTON.

In the early seventies, when I was a youth in the drawing office of a large steel and iron works in Sheffield, the idea prevalent amongst young men in steel or engineering works, or such of them as had ambition or a consciousness of ability beyond the average, was that if there were not sufficient opportunity of fairly rapid and well remunerated advancement at home there was at least an opportunity outside old England in the great republic of the west. From time to time one heard of migration of eager, spirited men to the United States of America, where there seemed to be openings with an ample scope for mental and physical activity for all who cared to venture. It is somewhat piquant to reflect that much of the remarkable development that has taken place in American iron and steel industries may be due to the brains of those young men who could not find sufficiently good scope to satisfy their ideas, or sufficiently good pay to satisfy their ambitions, in Great Britain.

There are not a few people who think that the development of American iron and steel industries will not only shake the supremacy of Great Britain at home and in the markets of the world, but will change the entire European situation. This involves an enquiry as to whether Great Britain has lost ground, and if so, some enquiry why she has done so, and a consideration of the probable consequences of the new competition.

There is little doubt that Great Britain has lost ground. The progress and development of a nation depend in some

considerable part upon the ideals or state of social opinion that obtain in the nation, quite as much as upon the possession of suitable raw materials of manufacture, the skill and capacity of its workers, and an advantageous geographical position. Economists on the continent of Europe have not hesitated to assert that a considerable portion of British supremacy in manufactures is due to the state of unhindered development that was possible in England, by reason of the conditions of peace within her borders. The conditions are certainly not favorable for successful manufacturing development if the factories of a country are liable to interruption, or even destruction, by sanguinary conflicts arising between nations territorially conjointed. Economists say, and say rightly, that England's long start in successful manufacture and the acquisition of riches would not have taken place if there had been periodical irruption of hostile feet within her borders, as on the continent of Europe. A feeling of comfortable security as regards interference from without not only produced a state of ease and wealth in England, but enabled her capitalists to undertake enterprises in all quarters of the globe to the benefit of the world at large. This feeling of ease, security, and supremacy was accompanied by certain disadvantages which may be briefly stated.

The landed interests in England, and in all European countries, have always regarded themselves as a caste apart from, and superior to, the other citizens of the state. A premium of social esteem has attached to the business of landowning, and to the pursuits and pleasures of landowners, which does not obtain with those having other occupations. A stigma, or an amount of social disesteem, is attached to those who do not belong to the landowning class, or to its closely attached and dependent professions. These facts are of great importance, since the landed interests have usually constituted the governing classes, with all the privileges and power that appertain thereto.

The natural heritors of the successful British manufacturers of the sixth and seventh decades of the 19th century have in many instances avoided the responsibilities incidental to manufacture, preferring to play the part of a country gentle-

man and to engage in the delights of hunting, shooting, fish-
ing, etc., rather than the less attractive pursuit of commerce.
To the state of social opinion hereby indicated may be traced
the decay of many factories, which well informed enterprise
would have kept vigorous and prominent. It has also kept out
of the ranks of manufacture many men of mental capacity,
who by reason of their trained intelligence would have been
capable of foresight, application, and enterprise that have
frequently been lacking.

It is an obvious circumstance that while the world moves
or while there is such a thing as progress in manufactures, the
factory installed by the latest comer is usually better than any
factory installed many years before. The newcomer has the
accumulated experience of his predecessors to guide him,
which naturally places him in a better position economically
than those who have to put up with disabilities that accrue
even in the passing of time.

England has built up her manufacturing position essen-
tially upon handicraft—the skill of the individual worker has
been the dominant idea amongst the masses of the English
people. Their intense individuality has scorned the idea of
mechanical aids to industry, quite as much for this pronounced
characteristic as from any fear of supplanted or displaced wage
earning capacity.

The supply of skilled and industrious workers in British
industries has usually been ample. The skill and capacity of
the better class individual English worker is on the whole to-
day, in the iron, steel, engineering, and allied trades, not in-
ferior to the skill and capacity of the worker in any other
nation. But while the best brains of America have been
devoted to the honorable pursuit of industry, to developing
mechanical ingenuity, to guiding, governing, and giving all
those general advantages which a trained intelligence confers,
such has not been the case in England. There were in Eng-
land not only conditions of luxury and ease, but social ideas
hindering trained and organized manufacturing development.

The first of commercial nations has not a system of educa-
tion fitting her sons to engage in commerce. The curriculum
of our great public schools and our great universities has suc-

ceeded in training men fitted for some of the learned professions, but as regards commerce, or most of the practical affairs of life, our young men have left the universities quite unfitted, and with the necessity forced upon them of learning all that was essential after their education was completed!

Given a state of luxury and ease, and a premium of social esteem upon members of any and all professions which did not obtain with the participants in manufactures and commerce, it is obvious to any sociological student that there must be loss of place in any struggle for world or social supremacy. When to this condition there is added a lulling sense of ease and comfort and an induced belief in the permanency of pride of place and power, a sense of individualism, and an ample supply of workers, it is not difficult to account for the present position of England.

Since the consolidation of Germany and something like an equal balance of military power in Europe the prevailing conditions of peace have permitted a steady and continuous growth of industrialism.

Nations, like men, first supply the wants of their own household before supplying others.

During the past twenty five years England has suffered a relative decadence of trade, and has not such a proportionately large share of the world's trade as she had at one time. Competition from without did not seriously disturb the mass of Englishmen, while the national sporting instinct says in effect, let all have a try and let the best man win.

It is no new thing for England to have competition in her iron and steel, and allied manufactures. Hitherto it has been called foreign competition, and the success of foreign competition is popularly explained by the brute force element in commerce, low prices. The reasons for successful foreign competition have been placed under the heads of cheap transport, low wages, long hours of work, and peculiarities possible under a protective duty system. Now that the competition from without is American competition, coming from our own kinsfolk, coming from such a quarter, it excites amongst English people in general quite a different state of feeling from that which obtained in regard to European competition. The prev-

alent view in regard to Belgian competition was, and is, that its success depends upon a standard of living and of comfort amongst Belgian workers inferior to that of the British workman, and the results are products inferior in quality and workmanship to average British ideas.

As regards German competition, although there were, and are, features in it undesirable of emulation, yet German workers were apparently better cared for than Belgian, and the enterprise of her manufacturers showed courage and perseverance, entitling German competition to respect. Enquiry has shown that on the whole German pig iron and the heavier iron and steel manufactures are not produced at lower costs than British. But when goods are sold below cost of manufacture for export, and the makers are compensated by high prices in a protected home market, which enable a recoupment of losses incurred in export trade, then a certain feeling of resentment is incurred. The average man settles the point in a common sense way by stating in effect, "If other people like to tax themselves in order to supply sugar, or iron, below the cost of production, more fools they. This process cannot go on forever, and in the meantime it is good business for the buyers or consumers anyway."

In order to estimate the effects of American competition it will be well to examine experience with other and preceding competition.

During the past twenty years the Belgian manufacturers of wrought iron have succeeded in taking from England a considerable share of the export merchant trade in wrought iron destined for markets over sea, where the question of price is of more importance than the quality of the article produced. Everyone engaged in handling Belgian iron would be able to testify from experience that the manufacturers thereof had, over a period of years, left themselves too small a margin of profit for possible contingencies to be able permanently to satisfy buyers who expected anything like precision of weights and sizes, or regularity of quality in their supplies. In past years it has frequently happened that the price quoted for Belgian iron has been five dollars per ton lower than the cost of any other iron obtainable on earth. It is clear that

this considerable disparity in price indicated either the measure of value in the estimation of the buyers, or an economic struggle amongst Belgian producers themselves to secure such orders as were going. The careful enquirer would ascertain that the lower prices at which Belgian products were offered were obtainable only by a condition of long working hours and low wages, such as English employers in general would be unwilling to see adopted in their own works, and such as English workmen in general would never accept without a struggle of prolonged intensity. Recorded mercantile experience shows that Belgian bar iron and sheet iron are giving way in favor of German products. The rapid development of soft steel manufacture by the aid of the Bessemer basic converter in Germany has led to German producers offering basic steel bars in merchant sizes and shapes, and basic steel sheets at prices equal to, and in some cases lower than those of the inferior Belgian products in wrought iron. The natives of markets like India, China, and Japan, were prompt to discover that German soft steel goods would work up better, and with less cracks, breaks, and failures than were common to Belgian wrought iron. The consignments from German steel makers were superior to those of Belgian makers, not simply in that superiority possessed by soft steel over low grade wrought iron, but in greater regularity of working to lengths, sizes, and weights. The eastern importer found, for instance, that the outturn of a parcel of German steel was more likely to accord with the invoice than was the case over an average of transactions with materials of similar shape of Belgian origin.

It is necessary to dwell upon this phase of competition for markets external to England, because it illustrates what will probably happen in any successful American competition for the trade of neutral markets. American competition is already more feared in Germany and Belgium than it is in Great Britain.

Ordinary merchant trade is more readily acquired, or lost, than that trade which is built up on specifications to meet engineering requirements, or in material ordered to comply with special conditions. On the engineering side I am doubtful of the ability of American steel masters to displace the use

of British steel in structural work, where American suppliers claim a limit of phosphorus in their steel of .10, while British masters, in the open hearth acid process, habitually work to a limit of .06. Every engineer knows that the lower phosphorus gives a better steel, safer in use, and will insist upon having low phosphorus while he can get it. Ordinary English steel rail makers have no difficulty in working to a limit of .08 phosphorus. In higher carbon steels, as now used for street and other rails, an English engineer will not accept a margin of 10 tons between the minimum and maximum breaking strains while he can get closer and better working. The tendency and the practice amongst English engineers is rather to raise the standard of quality than otherwise. Too much has been said, or presumed, as to the inferiority of British iron masters in blast furnace practice. It is true that the output from particular American furnaces, working rich ores, is superior in tonnage to British practice working on ores with a lower content of metallic iron. But figures that have come before me, from time to time, show that in the best practice the yields are good, and that pig iron is constantly being made in England with no higher consumption of coke per ton of pig produced than obtains in best American practice. There is at least one district in England, working on English ore, in which, under normal conditions, structural steel can be produced at as low a cost as any figures at present obtained in America, while if the close contiguity of coal to the Lincolnshire iron field, which of late seems assured, is taken advantage of, there will be British iron and steel masters capable of holding their own against all comers.

From time to time politicians in England—usually very unsafe guides in commerical matters—will be found publicly urging British manufacturers to alter their methods of doing business. Consular reports are published pointing out the deficiencies of Britain in certain particulars. When close enquiry is made into their recommendations their notions are found to be largely based on an idea that Englishmen should lower their average standard of quality and workmanship, or that they should give extended credit to buyers in countries that demonstrated in past years a financial inability to meet

their engagements at due date. Every man who has had practical contact with workmen or manufacturers knows how difficult it is to obtain from individual workers, or from an individual manufacturer, at one and the same time the best goods and the cheapest possible goods. In vain is it for those unfamiliar with details, or not in practical contact with manufacturing, to urge those who are engaged in producing to imitate their rivals or to embark on a trade in inferior goods. In practice manufacturers somehow get sorted out into grades suitable for particular markets, according to the nature and quality of their products. But England is now beginning to recognize that if she wants to keep and to extend her trade in British manufactures, she must find some means of diminishing the disparity in cost between her own products and similar manufactures of other nations. The English people are a watchful nation, whether in the small matters of domestic life or in the small economies of manufacturing life. England has been wasteful in not having developed her splendid possibilities by systematically educating and training her people. The commercial success which has been gained by scientific application and method in Germany, and the mechanical ingenuity of America, are the factors that are showing her how to economize in her methods and to cheapen her products.

So far as figures go, America will doubtless remain for some years to come the largest producer of iron and steel. But something more than quantity and cheapness of product is required, and that is, that these things shall be obtained with a general well being on the part of the workers engaged. Amongst other things to the credit of America, let it be said that her mechanical genius and industrial courage are making Europe understand that there is a dignity attaching to human labor, that man is worth something better than to act as a beast of burden, and where muscular devices can be employed to dispense with the use of mere muscular energy, such aids fit men for higher and nobler purposes, happier and more useful lives.

The future of European iron, steel, and engineering productions depends largely upon the ability to ensure continuous cheap supplies of suitable raw materials. America will doubt-

less contribute to the continuity of supplies or raw materials in the shape of pig iron, and partly manufactured steel. It is probable that there will be an increase in the number of factories in England established on the sea board in suitable districts, at which American pig iron, soft steel in blooms, billets, slabs, and bars, can be worked up and turned into various products to meet constantly growing needs of home and foreign markets. The ability to obtain such supplies from America will no doubt steady prices and prevent violent fluctuations in values in Europe. Machinery and tools, from the United States, where they specialize and promote intensity of production, will be bought and adapted in various ways to the special and local needs of European users.

German methods and American ideas are modifying British practice and British ideas in manufactures and commerce.

There is an anecdote told of two men, a German and an Englishman, who were discussing military matters somewhat energetically. The German clinched his argument by saying: "I tell you if a war were to break out all Germany would fight like one man." To which the Englishman replied: "And I tell you, if a war were to break out every Briton would fight like all England." This anecdote may be taken to illustrate the difference in mental attitude between England and her chief commercial rival. Englishmen learn with difficulty to combine amongst themselves to a common end, or to exchange information for the common good. Their respect for individuality is carried to extremes. More weight is attached to opinions than to the ascertainment of facts. But earnest and capable reformers are struggling to secure a scientific basis for the education and training of the people.

The most successful profit making British works are those where trained commerical intelligence dominates practical men, who are, however, invaluable in their properly subordinate positions. All these things are gradually being understood, and as they are more widely understood, will give rise to a feeling of dissatisfaction with the old men, the old methods, and the old factories which have outlived their period of usefulness.

American mechanical genius and cheap steel will not only raise the standards of comfort, but will multiply the wants of civilized mankind, which consumes more iron per head of population year by year.   But in seeking to create and sustain an export trade in steel, America will find Belgium and Germany her most formidable competitors—particularly Germany, whose manufacturers thoroughly understand the art of combination to insure immunity from external competition. During the past ten years there has been a striking increase in the number of factories throughout Germany, which are boldly conceived, well planned, and fitted and intended to last.

American competition will be more successful in British colonies, dependencies, and in neutral markets generally than in Great Britain itself, where it will act as a health producing tonic that England has wanted for many a day.

USES TO WHICH IRON IS PUT.

BY JOHN O'DONNELL.

[John O'Donnell, author and editor, is managing editor of the Pittsburg Chronicle-Telegraph; he has studied and written much on the iron industry as a result of investigations of the immense plants in the territory tributary to Pittsburg; he is a frequent contributor to newspapers and periodicals on these subjects.]

The United States is now making iron and steel at a rate never before attained, even for a brief period, and the question naturally is asked, Where is all the iron going? Steel is, of course, merely a form of iron. Pig iron, the result of smelting iron ore in the blast furnace, is the raw material from which finished iron and steel products are made, by removing slight impurities. Pig iron is now being produced at the rate of almost 22,000,000 gross tons per annum, and such a quantity, loaded on ordinary freight cars, would make a train over 10,000 miles long, or four times the air line distance from New York to San Francisco. At ordinary speed it would take three weeks for the train to pass a given point. The iron would make a girdle for the earth ten feet wide and an inch thick. Made into telegraph wire three sixteenths of an inch thick it would run a line to the sun, nearly a hundred million miles away.

Nearly all this iron is consumed in the United States. Although last year was, comparatively speaking, a heavy export year, only about one sixth the total was exported. The outside world makes some iron, also, its production in recent years lying between 25,000,000 and 30,000,000 tons, but these figures show how much the iron consumption of the United States exceeds that of the remainder of the world, relative to population. With only one eighteenth of the world's population, the United States is to-day consuming about two fifths of the total iron production.

This comparison makes still more pertinent the question, "Where is all the iron going?" The layman, if he lives in

the city, might reply that it goes largely into skyscrapers; if he lives in the country, that it goes into railroad rails. Either answer would be far from correct. Less than 5 per cent of the product goes into the framework of steel buildings. Rail tonnage varies, but this year it bids fair to be only about one eighth of the total.

It is the small uses of iron products which makes up the bulk of the tonnage. While there is in the United States about one mile of railroad for every 400 of population, new railroad building is far less active than it was in the late eighties and the railroads, which consume, roughly speaking, one half of the iron, find their consumption more in the direction of rolling stock, terminals and bridges than they do in rails. The great bulk of the rails which are purchased are for renewals, and not for extensions. Ten years is a long life for a rail where traffic is most congested, but traffic is really heavy on but a small proportion of the 210,000 miles of railroad operated in the United States.

A study of the channels of consumption of iron can best be made by considering the forms into which iron is made for ultimate consumption. Pig iron, which the United States is now making at the rate of nearly 22,000,000 gross tons annually, is, as remarked at the outset, merely a raw material. In its conversion into finished products there are important losses, which are only partially made up by the use of scrap or old material. A rate of production of 22,000,000 tons annually means only between 20,000,000 and 21,000,000 tons of raw material in which it leaves the rolling mill or foundry. In a total production of 22,000,000 tons of pig iron about 5,000,000 tons will be of grades which are used in iron foundries for the production of iron castings, including cast iron pipe and castings for machinery, railroad rolling stock and a great variety of small uses. Something like half a million tons will be refined before casting, and result in steel castings for somewhat similar uses. Roughly speaking, steel is simply pig iron with the bulk of the impurities removed and a small percentage of manganese or other alloy metal added. Another half million tons, hardly more, of pig iron will go through the puddling furnace and be converted

into wrought iron, differing from steel in many small respects, but chiefly in that manganese has not been added.

The remainder of the 22,000,000 tons of pig iron, say 16,000,000 tons, will be made into steel, to be rolled into finished forms. The losses in the operations and refining and rolling, diminished by the scrap added, will result in the production of approximately 15,000,000 tons of steel products, known as finished products from the standpoint of the steel mill. They are the finished product of the rolling mill, in that their further adaptation to the use of mankind is not accomplished by any rolling process, but by other operations. The structural shapes as rolled must be sheared, punched, etc., the wire rods must be drawn into wire through dies, the skein must be bent to a circular shape and welded to produce pipes and so on. For past years it would be possible to give an accurate presentation of the tonnage involved in the different forms into which the iron products have been converted, since excellent statistics are available, but the present rate of production of pig iron is fully one fifth greater than has ever been maintained for a calendar year, and it cannot be told with complete certainty how the different finished steel lines are sharing in the increase. A careful though necessarily tentative estimate of current production of rolled steel is given in the following table:

	Gross tons.
Plates and sheets	3,200,000
Rails	2,500,000
Wire rods	1,800,000
Structural shapes	1,500,000
Skelp	1,000,000
Bars, hoops, and miscellaneous	5,000,000
Total	15,000,000

A table similarly compiled to show the relative consumption fifteen or twenty years ago would look very different. The year 1887, for instance, marked the culmination of the great railroad building movement, and, while the production of pig iron in that year was only 6,417,148 gross tons, or only 29 per cent of the present rate, there were made 2,139,640 gross tons of rails, which is quite comparable to the present rate of production, while the production of plates and sheets was less than 625,000 gross tons, about one fifth the present

production, and wire rod production was about one seventh of the present. The country was then importing heavily of wire rods, and was importing all of its tin plates, included in the above table of current production under plates and sheets. Even with these imports, however, the consumption of sheets, plates and wire rods was, relative to the total, much less than at present.

Out of the total production of 3,200,000 tons of plates and sheets, about two fifths is No. 16 gauge (one-sixteenth inch thick) and thinner, the balance being thicker and running up to very heavy plates. The former is known by the generic term of sheets, but this category includes the sheets from which tin plates are made, the technical term for the sheet before it is coated with tin being black plate. About half a million tons of tin plate are made annually, the tin coating constituting an average of about 2 per cent of the total weight. Fifteen years ago no tin plate was made in the United States, and the demand was supplied by imports, but the greatest tonnage imported was 330,000 tons. It is astonishing that so light an article as tin plate should so run into tonnage, inasmuch as 100 pounds of tin plate of the average thickness will cover an area of 218 square feet, so that a production of half a million tons would cover an area of 55,000 acres, or eighty six square miles, giving thirty square feet to every inhabitant of the country. The ubiquitous tin can for food products explains over half the production; the remainder finds widely varied uses. The amount used in carpet sweepers is not inconsiderable.

Of sheets lighter than 16 gauge which are not tinned the production exceeds half a million tons. A portion is galvanized, a wholly misleading term signifying coating, with spelter (commercial zinc) by dipping in the molten bath. The uses are so varied that even the more important cannot here be given. Perhaps of no other steel product have the uses so increased of late years. In much building lath has given away to expanded metal as a basis for plastering, while the plaster itself has given away to steel sheets stamped in ornamental designs, particularly for ceilings. Factory buildings are covered with corrugated sheets. In electrical work

sheets laid together have largely given way to solid castings for fields and armatures, the efficiency being thereby greatly increased. This has given rise to a special product known as electric or magnetic sheets running into a very large tonnage. Sheet steel furniture, particularly filing cabinets, is no longer a novelty.

Of plates, or material thicker than 16 gauge, the avenues of consumption are equally varied, but a few stand out with more prominence than is the case with sheets. The chief line of consumption of steel plates at present is one which was unknown a decade ago and half a dozen years ago was one more of promise than of fulfillment, the steel railroad car. In a few brief years there have been built more than 100,000 all steel freight cars, and a third as many steel under-framed cars, the underframing being of plates. The all steel cars built have consumed more than 2,000,000 gross tons of iron and steel, over half this tonnage being plates. At the present time the car plants are turning out more than 200 all steel cars daily, a rate which, if maintained for 300 working days, would involve the consumption of 750,000 tons of plates.

Plates are used morethan for merly in the steel framework of large buildings, columns and girders built up of plates being used where formerly structural sections were employed.

Enormous gas tanks are now built, the one recently completed for the city of Milwaukee by a Pittsburg firm having a storage capacity of 6,000,000, cubic feet and requiring 3,500 tons of steel, chiefly plates. The second largest of such tanks is in Allegheny City, for natural gas, with a capacity of 5,000,000 cubic feet. Pipe for low pressure water lines is made of plates riveted together.

Passing over the item of rails we come to wire rods, of which about 1,800,000 tons are being made annually. The rods are drawn through dies into wire for the widest variety of uses to which any steel product is put. Wire nails are common. The United States is making from 10,000,000 to 12,000,000 kegs annually of 100 pounds each and last year exported nearly 1,500,000 kegs. Indeed, wire products are the most generally exported of any steel product. Of wire,

outside of nails, the United States last year exported 118,581 gross tons, but as far back as 1899 the exports amounted to 116,317 gross tons.

Of wire springs the consumption is enormous. The leading manufacturer issues a catalogue of nearly a hundred pages, devoted exclusively to springs, in which nearly a hundred different types are regarded as of sufficient general interest to the trade to be illustrated by engravings.

The production of wire has been steadily increasing at a rate slightly greater than that of total steel production, while the production of rails has increased much less rapidly than total steel production. It is confidently asserted that within a very few years the production of wire will actually exceed that of rails.

Structural shapes are now being rolled at the rate of about 1,500,000 tons annually. Together with plates and small quantities of other forms of iron and steel they are used for steel framed buildings, bridges, viaducts, etc. While such erection is spectacular it will be observed that it does not involve any very great relative consumption of iron. A considerable tonnage of structural shapes now goes into the manufacture of steel freight cars, which were at first made wholly from pressed steel plates. Structural shapes include I beams, channels, angles, zees, tees, etc.

Skelp is simply narrow, flat steel intended for the manufacture of wrought pipe by either the lap or butt weld process, the latter being used with the smaller sizes. About 1,000,000 tons annually are now being made. The pipe ranges in outside diameter from two fifths to 30 inches.

Of miscellaneous forms of steel there are now being rolled about 5,000,000 gross tons annually, including merchant bars, bands, hoops, cotton ties, nail plate for cut nails and spikes, fish plates, car axles, armor plate, etc. Merchant bars include rounds, flats, squares, hexagons, etc., and various special shapes, including those resembling ordinary structural shapes, but of less than three inches depth.

Outside of the easily recognized uses of hoops and bands a large tonnage is consumed for the production of articles which the layman would assume was made from plates.

Hinges, for instance, are made from heavy bands and not from plates. The difference might appear immaterial at first glance, but is vital to the hinge maker, since the band comes from the rolling mill of the proper width and requires but one operation of shearing per blank. Many similar articles are made from bands with a surprisingly small amount of manipulation, because the steel rolling mill has already given the material two of its required dimensions.

THE GENESIS OF THE UNITED STATES STEEL CORPORATION.

BY EDWARD SHERWOOD MEADE.

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The consolidations in the steel industry of the middle west, which were organized from 1898 to 1900, were generally regarded as industrial experiments. Their capitalization was based upon the predictions of their promoters that the experiments would be successful. Those predictions much time would be necessary to justify. Meanwhile the steel trusts were exposed to great and evident dangers. Competition from new enterprises was everywhere threatened. The future relations between the enterprises themselves were by no means certain to be harmonious. The profits of the promoters and underwriters were known to be large. In short, the position of the steel trusts was essentially speculative—a fact conclusively proven by the sale of their stocks at low values. If the values of these securities were to be raised to an investment level and kept at that height, these doubts and apprehensions must be removed from the mind of the investor. This could be done in no other way than by the passing of dividends and the building up of a large reserve.

The object of every corporate management should be to make its shares worth at all times their face value. If its position becomes so strong as to raise the value of its shares to a level which returns to the buyer no more than the investment rate of interest; if, in other words, a stock paying 6 per cent dividends commands an average price of 150,—then the acme of prudent management has been reached. In order that this strong position may be attained, it is of first importance that profits should be deferred, and that the corporation

should always pay out less than it earns, in order that an adequate surplus reserve should be accumulated. The surplus reserve of a corporation is that part of its net earnings which is set aside before dividends are declared. The effect of an adequate surplus reserve is thus to guarantee the dividend rate, and to cause the securities of the corporation so protected to sell for prices equal to or greater than their face value.

The amount of surplus required to give this standing to a corporation varies with the nature of the business and naturally bears a certain proportion to capitalization. This proportion should be increased with the irregularity of earnings or of expenses.

Iron and steel, although staple commodities, nevertheless, from the standpoint of the surplus reserve which is necessary to sustain the dividend rate of corporations engaged in their production, belong to the class of commodities whose demand is fitful and uncertain, and whose methods of production are constantly being revolutionized. The surplus reserve of a steel company should, therefore, be larger in proportion to its average earning power than the reserve of a railway corporation, if its securities are to sell at investment prices. Only by the accumulation of a large proportion of surplus earnings in a form in which they can be got at on short notice, can a corporation engaged in the manufacture of steel guarantee to the investor that, if he buys its securities, his sleep shall be sweet. European manufacturers recognize this necessity. They are extremely cautious in the payment of dividends, and their depreciation accounts are generally large.

A large surplus reserve is of peculiar value when earnings are suddenly threatened by competition. During the brief interval when the conflict is raging, this storehouse can be drawn upon to sustain the dividend rate; and the corporation thus strengthened can sail into the safe harbor of a pool or combination with its credit unimpaired and its financial reputation intact, while a few passed dividends might have inflicted a damage upon its reputation which a long period of subsequent good conduct might have difficulty in repairing. The American Sugar Refining company, for example, has been

able to beat off so many attacks without reducing, until recently, the rate of dividend upon its common stock, primarily because its directors have set aside a reserve of 20 per cent out of the earnings of monopoly with which to make good the losses of competition.

The accumulation of a large surplus reserve by a new form of corporation is peculiarly essential during the first stages of its existence, if its shares are ever to command high prices. The new enterprise has its reputation to make. A certain amount of speculative promotion has usually attended its foundation. Its shares have in the first instance been sold at low prices, mainly to brokers, on speculative orders. Conservative buyers hold aloof and await the development of its policy, desiring to know if the business is to be managed for the stockholders or for the stock market, and if the controlling interest proposes to stand by the corporation or sell it out to the public at the earliest opportunity. The surest, and indeed the only, way for a new corporation to attain an investment position is to resolutely adhere to the policy of reserve accumulation, and to refuse to pay dividends until its ability to pay dividends is unquestioned. This method of salvation may be tedious, but it is certain.

As already remarked, the steel trusts were in a position essentially experimental and speculative. It would seem to have been the plain duty of the management to have passed dividends and squeezed out the water in the capitalization of their companies by the accumulation of large surplus reserves. More especially was such a conservative policy required when the extraordinary profits of the steel trade during 1899–1900 are considered. The interests in control of the steel trusts, however, rejected a conservative policy; and all the companies paid the regular dividends on their preferred stocks from the date of their organization. The Federal Steel, American Steel and Wire, and National Tube companies, in addition to dividends on their preferred stocks paid a good return on the common. The explanation of these large dividends is to be found in the nature of the securities. The shares of the consolidations were divided into preferred and common stock. All of the preferred stocks included the cumulative feature,

which guaranteed to the purchaser that passed dividends would be made good before anything was paid on the common stock. This cumulative provision had been inserted by reason of the greater security which it carried with it. Preferred stocks which are cumulative as to earnings, and which, in the event of liquidation, constitute a preferred claim to assets, are hardly inferior to mortgage bonds and are superior to ordinary debentures. The owners of plants were more willing to receive such securities in exchange for their properties than if the promoter had offered only one kind of stock for all purposes.

This cumulative feature, however, although a valuable aid to speculative promotion, was a serious obstacle to the accumulation of surplus reserve. It was impossible for the steel trusts to decrease their liabilities by the passing of preferred dividends, because the passed dividends remained alive as deferred claims to future earnings. It is true that the directors might, with perfect safety to the corporation, have allowed the preferred claims to accumulate to any amount. The back dividends need never be paid, and an adequate surplus could in this way be gathered for future dividend payments on the preferred stock. But the morality of such a course, in view of the existence of an amount of common stock equal in par value to the preferred, which had been purchased in good faith by large numbers of people, would have been doubtful. No matter how necessary the passing of their early dividends and accumulation of large reserves by the steel trusts may be judged to have been, so far as the preferred stock was concerned, in view of the cumulative provisions included in the contract with this class of stockholders, it was impossible.

The payment of dividends on the common stock was less imperative; but here also there is much to be said in justification of the course pursued. The promoters had made promises that common stock dividends would be paid. The earnings of the corporations were apparently large. The preferred stockholders were receiving their dividends, and to the holders of common stock it seemed unreasonable and unjust that, in such prosperous times, a discrimination should be made in favor of the preferred stock. The reputation of the

management of many of the industrial combinations was seriously injured by their failure to redeem their promises of dividends on the common stock. It is not at all to the discredit of the steel trusts that they made every effort to treat both classes of stockholders alike. It is true that the payment of large dividends was in line with the advantages which would accrue to promoters and underwriters from the sale of their stock holdings. It is also true that the payment of dividends was a direct appeal to the speculative demand, and was opposed to the permanent interests of the corporations. Considerations such as these have been made the basis of censure of the interests in control of the steel trusts. They have been accused of mismanaging the affairs of the corporations in the attempt to sell their stocks; of unloading their own shares upon a credulous public improperly influenced by their false representations of earning power; and of draining the resources of their properties in an unscrupulous attempt to sustain the value of their watered stock. These charges may be well founded in a few cases, such, for example, as that of the management of the American Steel and Wire company; but, in general, there is no basis for them. It might indeed happen that, even if conditions had permitted the accumulation of surplus reserve, stock market considerations would have interfered with the adoption of a conservative policy; but, as matters actually stood with the companies, there was little discretion left to the directors.

Although the policy of dividend payment was necessary in view of the charter provisions of the companies, this necessity only throws sharper relief into the unwisdom of those who framed those charters with their separation of stock into two classes and their cumulative reservations,—provisions which were opposed to the accumulation of necessary reserves, and which worked, therefore, directly against the permanent interests of the corporations. Cumulative preferred stock is a double faced security. It is in reality a bond sailing under false colors, calling for an excessive return, and injuring, by its unreasonable claims, the junior security united with it. It is a makeshift, adopted by promoters to make sure of universal assent to their proposals. It has long since been ban-

ished from railway financiering, and its recrudescence in the industrial charters is a step backward in financial methods.

The pursuit of this policy of dividend payment soon found the steel trusts in a position which invited attack. The small amount of their surplus reserve was in striking contrast with their gigantic profits, out of which, if the corporations had been properly organized, large reserves could have been accumulated. All the water of combination still remained in their systems. But little of the shadow of anticipated profits had been replaced by the substance of actual earning power.

The directors did all in their power to build up the properties placed in their care. With one exception, and that a doubtful exception, there is no evidence to show the business of the steel trusts was not honestly and ably conducted. Whatever could be done to improve the properties was thoroughly accomplished. Considerable economies were effected; and, in particular, the selling methods were so revised as to greatly increase earning power. The policy of the management in every direction but one was a distinct advance over the former methods of the trade. But in that one exception lay the root of the whole matter. The policy of dividend payment and small reserves was, in reference to the financial position of the steel trusts, the dead fly in the ointment. The safety and stability of the consolidations were sacrificed to the unreasonable claims of their securities.

The effect of this policy had been to unfit the consolidations to withstand competition. With inadequate surplus reserves and with high speculative values established for their shares, any reduction of the earnings of the steel trusts was to be feared by their stockholders as a calamity from which there could be no recovery. Such a competition, invited by the policy of the consolidations, confronted them in 1901. The origin and nature of this threatened competition will now be considered.

The manufacturing companies which were originally merged into the United States Steel corporation may be divided, on the basis of their products, into two classes. The Carnegie Steel company, the Federal Steel company, and the

National Steel company were large producers of steel billets, ingots, bars, plates, and slabs,—products not yet in their final form, and constituting the materials for other branches of the iron and steel industry. The second group, including the National Tube, American Steel and Wire, American Tin Plate, American Steel Hoop, and American Sheet Steel companies, were, as their titles indicate, producers of finished steel goods. They obtained most of their materials from the primary producers of steel, and converted them into wire, pipes, tin plates, sheets, cotton ties, and structural material. These two groups of companies, from their location and from the nature of their products, had large dealings together. The Federal Steel company furnished the western plants of the American Steel and Wire company with most of their wire rods, and furnished steel billets to the Ohio plants of the National Tube and American Bridge companies. The Carnegie Steel company found its principal market among the finishing mills of the Pittsburg district, including representatives of all the members of the second group of producers. The National Steel company supplied a portion of the demands of the Tin Plate, Sheet Steel, and Steel Hoop companies, whose financial control was identical with its own. Between these companies, until the fall of 1900, there was no reason for competition. The mills of the Carnegie company in Pittsburg were five hundred miles distant from the principal plants of the Federal Steel company in Chicago. The National Steel company, although its mills were, properly speaking, within the Pittsburg district, was not yet strong enough to come into serious conflict with the Carnegie Steel company. As for the finishing companies, their products were so entirely distinct as to afford no ground for competition. So long as the active demand for steel, which had begun in the winter of of 1898–99, should continue, there seemed to be little danger of conflict. Every company was fully occupied, and had no need to go outside its own province to keep its mills running.

The harmony of interests among the various companies, however, was unstable, depending, as it did, upon a restriction of each producer within his own field. With the reaction in the steel market which began in the spring of 1900 and con-

tinued until November of that year, it became evident that the trade must adjust itself to a smaller margin of profits; and the conflicting forces, which had been held in abeyance during the season of prosperity, became alarmingly active and threateningly evident.   The stock capitalization of the recently formed consolidations was based upon the large profits of 1899.   If dividends were to be continued during periods of reduced demand, every effort must be made to strengthen the position of the companies by reducing expenses.

No sooner were the new companies fairly upon their feet, and had realized the necessity of greater economy, than they began a movement which looked toward the attainment of an independence in raw materials similar to that which the Carnegie company had already achieved.

The Carnegie Steel company owned the most complete, the best equipped, and the best managed steel plant in the United States.   No one of its rivals was worthy to be compared with it in point of self sufficiency of production.   This equipment supplied ore and fuel to the mills which were grouped so closely about Pittsburg that the president of the company was able to visit some department of each mill on successive days.   The Edgar Thompson furnaces and mills were at Bessemer, two miles from Pittsburg; the Duquesne furnaces and mills, four miles from Pittsburg; and the Homestead Steel works, one mile from the city.   Besides these larger works, there was located in or immediately adjoining the city the upper and lower Union mills, the Carrie and Lucy furnaces, and the Howard Axle works.   All these plants were connected by the Union railway, with thirty nine miles of track, which in turn connected with the Pittsburg, Bessemer & Lake Erie railroad to the north.   This arrangement of mines, coke ovens, and mills, was the most favorable that could have been devised for economical production.   The mills of the Carnegie Steel company were concentrated at the point of largest present advantage, where materials could be most easily assembled, and from which the largest markets could be most easily reached.   It was this fact of concentration, even more than their superior facilities, which gave to the Carnegie company their most pronounced advantage.

The advantages of the Carnegie company did not stop here. Their mechanical equipment was superior to that of any other mills, and their business was the best managed of any in the country. It is not meant by the first statement to imply that the consolidations did not include individual plants which were the equal of the Carnegie mills. The plant of the Ohio Steel company at Youngstown, for example, was not inferior to anything in Pittsburg. It is, however, true that the average excellence of the Carnegie equipment was far above the average of any of its rivals.

The management of the Carnegie company represented the acme of productive efficiency. Every officer had risen from the ranks by sheer dint of compelling merit. Every head of a department had an interest in the business apart from his salary. Trade unionism had been banished from the mills in 1892, and the workmen were spurred by high wages and the promise of advancement. No visitor to the Carnegie mills can fail to be impressed with the intensity of the effort and the strained attention evident in every department. The result of these advantages appeared in the revelations of the Carnegie-Frick controversy, when the plaintiff claimed that the total profits of the company for 1898-99 exceeded $70,000,000. Such was the company that threatened the steel trusts with its competition.

The results of this competition were clearly foreseen by those in control of the consolidations. In view of the inadequacy of their surplus reserve, taken in connection with their other disadvantages, a general decrease in profits would be the signal for the passing of dividends, and a heavy fall in the value of their stockholdings. Not only this, but industrial warfare demands new appliances and large construction, which could only be paid for by issuing bonds or adopting the more dangerous course of increasing the floating debt. In either event the decline in the value of stocks due to decreased earnings would be fixed and confirmed for years by placing fixed charges ahead of dividends.

Not only were the leaders of the steel trusts under obligations to their stockholders to prevent the threatened disaster, but considerations of private advantage inclined them

to the same policy. There were only two ways by which the controlling interests of the steel trusts could avert the impending calamity. One was to make an abject surrender to the Carnegie company, thereby confessing their inferiority, inflicting a severe blow upon their already doubtful credit, giving up all the plans of industrial independence which had been included in their schedules of advantages, and upon the attainment of which their capitalization had been in part based, and leaving the danger of competition still present and no longer concealed; the other to adopt a plan which should harmonize all the conflicting interests by uniting them into one corporation, organized, like the Federal Steel company, to own a majority interest in the various steel companies which it was necessary to control, and in this way to remove the danger of competition. In a declining stock market the second alternative could hardly have been chosen. But, in the great bull movement which culminated in May of 1901, all things were possible. The United States Steel corporation was backed by the strongest financial houses in the United States. It included the Carnegie company, the strongest steel company in the world; it completely realized the ideal of independence, for which all the merging companies had been striving; it exorcised the forbidding spectre of competition; and it was offered to the public at a time when the speculative mind was able to appreciate these advantages at something more than their real value. Out of this favoring conjunction of circumstances, was evolved a corporation with a capitalization of $416,000,000 in excess of the combined capitals of the merging companies, out of which has been taken a large amount of ostensible profits in bonuses, premiums, and commissions. The details of the organization, the motives to which the promoters appealed, and the financial prospects of the new company are matters not for discussion here. The outcome of the present investigation is that the primary advantages sought in the formation of the United States Steel corporation were the avoidance of competition, and the guarantee of permanent stability and harmony in the steel trade in the middle west.

THE ENTERPRISES BUILT UP BY ANDREW CARNEGIE.

BY CHARLES M. SCHWAB.

It would seem a work of supererogation to present, in a succinct sketch of Andrew Carnegie such as this aims to be, the chronology of his life at length; for many biographers have made familiar the very interesting story of his notable career, from his humble origin through three score and five years, showing the subject in his successive stations as the bobbin boy, telegraph messenger, telegraph operator, railway superintendent, manufacturer, and philanthropist.

Much less relevant would be the rehearsal of all the many striking incidents of Mr. Carnegie's life, particularly during his boyhood struggles, in a retrospective survey of the quarter century of his life during which he was facile princeps in the development of the American iron and steel industry and in placing the United States foremost of all the nations in that important branch of manufacturing.

Mr. Carnegie's advent into the field of metallurgy followed his retirement from the office of superintendent of the Pittsburg division of the Pennsylvania railroad. That was just forty years ago, when, it may be said, he was a young man, albeit he will doubtless resent the imputation that he is not still in the heyday of youth. The office of superintendent of the Pittsburg division was not, during Mr. Carnegie's incumbency, the sort of fat satrapy it is to-day, and his emoluments were beggarly ($1,750 per annum) compared with those of R. P., as my distinguished friend, Mr. Robert Pitcairn, the present Pittsburg head of the Pennsylvania, is popularly apostrophized. Mr. Carnegie had, more-

over, invested the little he had in Adams Express company's stock and a share in the famous Storey oil farm, so that when the Cyclops Iron works, the primordial Carnegie enterprise, was decided upon, the founder, reluctant to disturb these small investments, was obliged to borrow his share ($1,250) of the funds needed to finance the undertaking.

The Cyclops company was formed October 14, 1864, to establish an iron rolling mill to supply material to the Keystone Bridge company, which was organized six months later. Mr. Carnegie resolved upon these ventures while in the service of the Pennsylvania, as a result of successful experiments the railroad company had made with an iron bridge. He foresaw the great possibilities for the iron trade in this direction, and with the self reliant initiative which has ever characterized his life set about to establish himself with others in the business. The organization of the bridge company marked an important epoch in the railroad development of the country and the progress of the iron trade. It was precursory to the general substitution of metal for wood and masonry in railway bridge construction and to the opening of a new and prolific realm to the nascent iron industry.

Associated with Mr. Carnegie in the foundation of the Cyclops plant, which, as its name imported, was really a prodigious enterprise for those uncertain days of civil strife, were Aaron G. Shiffler, J. L. Piper, Thomas N. Miller, Thomas Pyeatte, and John G. Matthews. The Keystone company included Aaron G. Shiffler, John L. Piper, Walter Katte, and James Stewart. About the same time the Union Mills, built in 1861-2 by Kloman & Phipps, were acquired by a company including Andrew Carnegie, Thomas N. Carnegie, Henry Phipps, Jr., Andrew Kloman, Gustavus Praetsch, J. L. Piper, Aaron G. Shiffler and Thomas N. Miller. Of these pioneers Mr. Phipps alone remains to share with Mr. Carnegie the fruits of the sapling which they planted four decades since. The growth of that sapling has been phenomenal and incessant, being comparable now only with the gigantic redwood of the California coast ranges, a marvel of size and strength. More fitting names than Cyclops, Keystone, and Union could not have been given to the enterprises upon and around which

the various concerns comprising the Carnegie company were reared.

The Keystone company built the first 300-foot span metal Bridge over the Ohio and has since erected many of the largest steel structures throughout the country. The business expanded rapidly during the boom in railroad building after the American Civil war and received a great impetus when steel was adopted for building purposes. Soon after these works began operation, it became necessary to provide an independent source of pig iron supply, and the Lucy Furnace company was formed and built a small stack which was blown in May 11, 1872.

The manufacture of steel by the Bessemer process was taken up in 1874, the Edgar Thomson Steel company, limited, being organized by Mr. Carnegie and others for that purpose. This company was capitalized at $1,000,000 and built a plant for rolling rails, consisting of a Bessemer converter and a rail mill. The American steel rail industry was then about seven years old, and, under the Morrill and supplemental protective tariffs, had attained considerable proportions, although imports continued from England. The Illinois, Pennsylvania, Cambria, and Bethlehem companies had entered the trade in the order named between '65 and '73, but it was not until 1867 that home made Bessemer steel rails were laid for the first time in place of iron rails. The prices ranged from $174 per ton in March, 1868, down to $95 per ton in January, 1872. In 1870, when it was proposed to place a duty of $28 per ton on foreign rails, the Hon. S. S. Marshall, a prominent member of the house, made a strenuous protest, declaring that the duty would make the cost prohibitive. On the contrary, prices declined, but not for English rails. Four years after the duty was imposed, American rails sold at $94.25 per ton, and a year later, when the Edgar Thomson plant was put in operation, a marked decline resulted, the average for the year being $68.75 per ton. Rates were scaled down steadily thereafter as the manufacturers improved their facilities and reduced the cost, until the ephemeral boom between September, 1879, and February, 1880, when rails advanced from $50 to $85 per ton, the average for the two

years, however, being about $57. Since that time prices have declined steadily, the average for the last twenty years being about $33, and since 1890, $26 per ton.

This somewhat discursive bit of history is interesting in this connection as showing the growth of the most important branch of the American steel industry, in which Mr. Carnegie and the Edgar Thomson works have been the leading factors. For many years after the introduction of the Bessemer process in the United States (1864), the product was used in the manufacture of T rails almost exclusively, but gradually it supplanted puddled iron for structural purposes and the manufacture of rods, nails (1883), and other finished forms. The increased demand for Bessemer steel arising from this evolution was met, or in many cases anticipated, by Mr. Carnegie and his associates, and from time to time the works were enlarged or other steel plants and rolling mills purchased.

The Homestead steel works, built in 1880–1 by the Pittsburg Bessemer Steel company, and the Duquesne steel works, built in 1886–8, were thus acquired. Both plants had small Bessemer converters and rail trains originally, but the rolling of rails at Homestead was discontinued in a short time, and at different periods subsequently other lines were taken up, including the open hearth steel making process, the rolling of steel structural shapes, ship and tank plate, and the forging of warship armor. The Duquesne plant has also been enlarged, and now includes four of the largest blast furnaces in operation, while an extensive plant for making open hearth steel is under construction, in addition to several rolling mills.

The growth of the Homestead works has probably been more rapid than any like establishment in the world, and may be ascribed largely to the extended use in recent years of basic open hearth steel. The first open hearth plant, built at Homestead in 1886, comprised a small number of basic and acid furnaces. The acid process was after a thorough trial discarded entirely, and additional basic furnaces were constructed. The open hearth steel production of the whole United States in 1886 amounted to only 218,973 tons, as against 2,269,190 tons of Bessemer. In one year the Homestead works produced about 1,000,000 tons, or

34 per cent of the open hearth output of the United States, which was nearly equal to the total output of the entire country only fourteen years ago.

This remarkable development, it may be observed obiter, is a significant sign of the times in the steel industry, denoting as it does the increasing preference for open hearth over Bessemer steel in cases where the use of either is optional. For the last few years the production of Bessemer steel has increased 25 per cent and of open hearth 31.5 per cent. The introduction of the pressed steel freight car partly accounts for this, but the increase of production is due primarily to the improvement in manufacturing practice and in the quality of product. It may be added that the open hearth process will continue to gain on the Bessemer, and many believe that the latter is going slowly, step by step, the way of the puddling furnace; but the time for numbering its days of usefulness is still remote. However, the additions to productive capacity now building and projected in the United States are in the great majority of cases for open hearth steel. In England the advance of the open hearth furnace has been even more marked than in the United States. The change, it may be said, has been accelerated in that country largely by reason of the failing ore supply, with the consequent shortage of Bessemer iron, necessitating recourse to the open hearth process, which uses scrap iron and steel, the supply of which is comparatively abundant. The Bessemer process lost first place in the British steel industry some years ago, the output being only 38 per cent of the total steel product. Bessemer still holds first place in the United States, the output amounting to 72 per cent of the total, which, however, is a loss of 10 per cent in six years.

The Carnegie industrial system, which now embraces the mining and transportation of ore by rail and water and the manufacturing of coke, is the growth of years and represents the enterprise of the man who laid the foundation. In this respect it is unlike many contemporaneous organizations recently formed in the steel trade, comprising numerous small concerns originally competitive and created by many individuals.

The iron and steel manufacturing plants of the company include 19 blast furnaces, 3 steel works with 8 Bessemer converters and 56 open hearth furnaces, 5 rolling plants with 34 mills, an armor plate works, and a forge for the manufacture of locomotive and car axles. These are all Cyclops worthy of the Homeric archetype. The works enumerated, with the improvements under way and completed, will have an aggregate capacity of 3,430,000 tons of steel per annum, equal to 32.56 per cent of the production of the United States, 12.65 per cent of the output of the world, and nearly 71 per cent of the production of Great Britain.

In recent years extensive mines of rich iron ore were added to the company's possessions in the Lake Superior region, and it now mines about 25 per cent of the output of the district. From the docks at the lake shipping ports the ore is carried in vessels owned or chartered by the company to Conneaut harbor, Lake Erie, where it is transshipped by rail 153 miles to the furnaces via the Pittsburg, Bessemer & Lake Erie railroad.

The magnitude of the steel manufacturing operations of the present day may be appreciated from the fact that in a year the receipts of raw material and shipments of finished product of the three largest Carnegie works aggregate 16,000,000 tons, which, according to Mr. J. T. Odell, equalled the combined tonnage handled in one year by the Missouri Pacific, Southern Pacific, and Northern Pacific railways, operating 13,000 miles of track, 1,500 locomotives, and 50,000 cars. In the mining, transportation, and manufacturing operations the company provides employment for about 50,000 persons, and disburses yearly about $50,000,000 to its operative and administrative forces. The business transacted is exceeded by few, if any, commercial organizations in America or Europe.

When the reason for the remarkable success of Mr. Carnegie and the business bearing his name is sought, it is easily perceived. Americans, and particularly those within the Pennsylvania coking coal area and the iron ore fields of Minnesota and Michigan, need only look around them for the principal cause. Mr. Carnegie simply availed himself of the natural riches indigenous to those favored regions, without

which America would not be the leading producer of iron and steel in the world, or Pittsburg the officina gentium. As one well informed writer observed a few years ago, the United States would still be in vassalage to Europe for many iron and steel products but for Lake Superior iron ore and Connellsville coke.

Andrew Carnegie, however, with the prescience which seems to be a common attribute of the Scot, saw or made the opportunities of the early days of the iron industry, grasped them by the forelock and put his faith and capital into the business with invincible confidence. From the outset he held firmly to the conviction that the United States would in time surpass all other countries in iron and steel making, and he has never hesitated at any risk or sacrifice, however great, which promised to advance the industry. Having assisted in placing America in the lead of all the iron and steel manufacturing nations, Mr. Carnegie's single purpose has been to secure the position thus attained by striving unceasingly for the most economical means in the utilization of the country's resources. Starting with the practice which the English preceptors gave with the fundamental iron and steel processes, imposing an everlasting obligation at the same time, America has, thanks to Mr. Carnegie, evolved a system in blast furnace, Bessemer and open hearth steel making, and rolling mill operations, essentially distinctive from the original, and conceded to be far in advance of the best European methods.

During this transition Mr. Carnegie has frequently been called upon to make large expenditures for new appliances to replace those which had been but recently adopted, and he has done this cheerfully, for with him the best is good enough only until something which promises a better and cheaper product is offered. He has willingly allowed the profits of the business to be taken year after year for experiment and improvement, whilst our friends across the water, content with the crude, anachronic system of bygone times, took the dividends and kept the even tenor of their way. The corollary of this reduced to figures shows that the United States now produces 39.25 per cent, Germany and Luxem-

bourg 23.20 per cent, Great Britain 18.44 per cent, and the Carnegie works 10 per cent of the steel output of the whole world, the Carnegie production being equal to more than one half of the aggregate output of all the works of Great Britain.

For many years the traveller on the Pennsylvania railroad passing Braddock may have observed a broom of immense size towering far above one of the Edgar Thomson furnaces. This broom, as new methods of furnace working were introduced from time to time, was shifted from one stack to another, but it remained always with the Edgar Thomson group, signifying that the furnace over which it was raised had made a clean sweep of the furnace record of the world. The broom finally came down for good, but it was another, or rather several other Carnegie stacks which brought it down when the Duquesne furnaces were put in operation. The breaking of records since has been of such common occurrence that the broom was dispensed with, as the necessity for shifting became too frequent and troublesome.

The capacity of the blast furnace since the first Lucy stack was built in 1872 has been increased from less than 100 to more than 600 tons per day. The development of the blast furnace is fairly indicative of the progressive march in every branch of iron and steel making as carried on by the Carnegie company, from the mining of the ore and coal through the entire scale of operations to the final handling of the finished steel. During the 36 years Mr. Carnegie was identified with the industry, the works under his control fabricated over 50,000,000 tons of iron and steel for the multifarious uses of civilization, making possible the construction of many miles of railroad that could not have been built had he not been the actuating force in revolutionizing manufacturing and competitive conditions.

Mr. Carnegie has been not only the architect of his own fortune, but has opened the door to opportunity and wealth for many men, sharing his success at all times with his employees and business associates with unexampled liberality. He has made many young employees partners in the business for meritorious service, assigning to them, virtually without the payment of a penny, valuable stock interests, requiring

payment only from the profits of the shares, that they might not consider such transfers as gifts but as their due. The first charge on the revenues of the business is for the best paid labor in the world, and Mr. Carnegie makes it a paramount obligation to maintain that standard and to provide steady employment for the thousands whose welfare is in his keeping.

The public philanthropies to which he has devoted millions aim to be practical and are characteristic of their creator, but perhaps the most wisely conceived benefaction of the many he has originated was instituted some years ago for the employees of the steel company. The cardinal canon of his famous gospel of wealth and the governing motive in all his philanthropic efforts is to help those who try to help themselves. This doctrine was put into practice first when he established a savings and loan fund for the employees, and put a premium on thrift and economy by obligating the company to pay everyone who deposited his savings with the company a higher rate of interest than could be obtained from any public savings institution. The company has done this ever since, paying a fixed rate of 6 per cent annually, regardless of business conditions, deficits in interest earnings, or the fluctuations of saving bank rates, and, in consequence, the fund now has a larger number of depositors with a higher average of deposits than any of the public savings institutions in the mill localities.

For the purpose of enabling the workmen to acquire their own homes, loans are also made from this fund on more liberal terms than can be obtained otherwise, and many of the workmen own comfortable dwellings secured by the assistance thus given. Every department foreman and paymaster in the various works is authorized to receive deposits, and the many chances afforded the workman by this arrangement to put by surplus earnings to his credit with the company before he leaves the works on pay day, have been an effective means of helping him not to squander his money, for the temptations to spend freely and foolishly which beset the average workman before he reaches his family with his earnings are many, and to a large number, irresistible. The company, in addition

to guaranteeing the high interest rate, which is about double the amount allowed by banks, assumes responsibility for the entire running expenses of the fund, giving the services of the accountants and clerks needed to transact the business without charge upon the depositors.

While Mr. Carnegie has done much and promises to do more to enrich the race by giving millions to foster what he considers the best adjunct to the public school in the advancement of popular education—the free public library—yet he counts the satisfaction of distributing his wealth as naught compared with the pleasure he has given others in the making of it; for he believes with the philosopher that the highest reward of life's labor is the enjoyment of seeing others benefit by it. That he has been able for so many years to provide the means of livelihood for thousands with good wages and steady employment, helping at the same time to cheapen and extend the use of the principal manufactured product of the country, is to Mr. Carnegie far more reason for gratification than the realization of his best laid plans for disposing of the income.

THE STEEL TRUST AND ITS MAKERS.

BY CHARLES S. GLEED.

[Charles Sumner Gleed, lawyer; born Morrisville, Lamoille Co., Vt., March 23, 1856; educated in the public schools of Lawrence, Kans., 1866-76; student in the university of Kansas Law school; admitted to the bar in 1881; was for twelve years trustee Kansas University; in law or traffic departments Kansas, Pacific, Union Pacific and Atchison, Topeka & Santa Fe Railway companies, 1880-4; editor Denver Daily Tribune 1884; proprietor Kansas City Daily Journal. Author of many political, legal and descriptive articles and addresses.]

The United States Steel corporation, of New Jersey— unlimited! How absurd the word limited would look attached to the name of this company which began life with a capital stock of one billion one hundred million dollars and a bonded debt of three hundred and four million dollars. This is the first billion dollar business corporation on earth. Three tramps were playing poker in a box car, with corn for chips. The first bet one thousand dollars; the second raised it a million; the third made it a billion. "Take the pot," said the first, "take it, you educated son of a gun; I don't know how much it is!" No man knows how much it is—not even Mr. Morgan. To know how much it is one would have to know familiarly all the mines, mills, machinery, buildings, lands, and appurtenances in this vast property. No one head can hold so much. The facts in this case are worth considering.

In the organization of stock companies the prevailing idea in the past has been to keep down the issue of shares to the lowest possible figure consistent with convenience in certifying the ownership. Thus banks like the Chemical, and insurance companies like the Equitable, have small capitalizations bearing no particular relation to the value of the assets. In the case of banks vast sums of money have been paid in or accumulated as surplus which might as well as not have been represented by issues of stock. The present ruling fashion is to capitalize companies on the basis of things hoped for, the evidence of things unseen. Railway and mining companies are said to have set the pace. The strictly private corporations have always done as they pleased in this respect without

serious objection or criticism; but railway corporations have been severely criticised for large capitalization because of the theory, more or less firmly fixed in the public mind, that the public has a right to limit railway earnings to a low rate of return on the actual money invested in the property. In late years most of the newly organized industrial corporations have adopted the much paper plan. This is probably done on some dim theory that ten pretty pieces of paper will sell for more than one. Shares of stock stand for only fractions of ownership. If such shares were expressed directly in fractions instead of circuitously in dollars, perhaps much of the charm of high capitalization would disappear. Thus one share of United States Steel corporation stock looks like one hundred dollars. If such share were described as one eleven millionth of the whole, it would not be so attractive. The new steel company chose the high capitalization plan and, with its one billion one hundred millions of stock and its three hundred and four millions of first mortgage bonds, now undisputedly holds the center of the stage in the corporation world.

Few casual observers comprehend to what an extent iron has become king. Nobody knows when iron was unknown, yet the fact remains that the modern use of it makes the ancient use of it seem ridiculously small. Five hundred years ago the world used, as nearly as the guessers can tell, only a few thousand tons a year—say fifty thousand tons. The use now is near fifty million tons. In the United States the first iron workings were operated between the years 1600 and 1650, the annual output for that period averaging about one thousand tons. Last year the output of this country alone was about fourteen million tons, which put us about five million tons ahead of our chief competitor, Great Britain. This brief reference to statistics is enough to show the possible foundation for such a corporation as the one we are considering, though a word as to why the use of iron has so wonderfully increased in such a mere instant of time will not be out of place. The discovery of the process of treating iron so as to make steel worked a revolution in the adaptability of iron to industrial uses. Thus a steel rail is as much superior to an iron rail as a steel razor is to an iron razor. In the quarter of

a century beginning with 1855 the processes of steel making, substantially as now conducted, were discovered by Sir Henry Bessemer and others in England and on the continent. Early in the sixties the first steel rails were made in England, and late in the sixties the first in this country were made—in Pennsylvania. This country is now making over ten million tons of steel per year. The present great uses for steel, which a century ago were scarcely dreamed of, are for railroads and their equipment, ships, building frames, bridges, telephone and telegraph wires, fences, piping, tools, machinery, and an infinite variety of small articles such as nails, tacks, toys, beads, wagon and bicycle wheels, house decorations, etc. Now that these changes have come to pass, hundreds of others are in contemplation. Railroad men are wondering how long it will be before they can afford to use steel for ties, telegraph poles, small station houses and many other purposes. Builders and others are also contemplating many new uses for steel. The United States Steel corporation is really founded on these facts and conditions.

As long ago as 1899, at least, the newspapers of New York made somewhat frequent mention of the possibility of the formation of a giant steel trust, or corporation, which should gather in the principal steel companies of the country. The first information of a definite intention to accomplish the proposed union reached the public in 1900, when such an attempt was made. This attempt failed.

After many rumors and reports, on Saturday, February 23d, 1901, in New York, an agreement to form the new company was reached. The reported makers of this agreement were J. Pierpont Morgan and two of his partners, Robert Bacon and Charles Steele; Francis Lynde Stetson, attorney for the Morgan firm; William Nelson Cromwell, attorney for the National Tube company; Judge Elbert H. Gray, attorney for the Federal Steel company; Max Pam, attorney for the American Steel and Wire company; Victor Morawetz, attorney for parties in interest; John W. Gates, of the American Steel and Wire company; Charles M. Schwab, of the Carnegie company; E. C. Converse, of the National Tube company, and Judge William H. More, who represented the National Steel

company, the American Tin Plate company, the American Steel Hoop company and the American Sheet Steel company. The companies now in the great company are those above mentioned and the American Bridge company and the Lake Superior Consolidated Iron mines. This last, known as the Rockfeller iron property, was organized in 1893. It owned and operated large iron mines on the Messave Range in Minnesota, and owned the Duluth, Messave and Northern railway with one hundred and thirty two miles of track.

These constituent companies were themselves the result of great consolidations. Many hundreds of properties all over the country, doing like lines of business, had been brought together under the names quoted. Each one of the companies named had made up its list of companies which seemed naturally to belong together; had computed the possible economies, total earning power, etc.; had translated the possible net profits into capital and issued securities accordingly for the acquisition of the properties. Examine, for example, the American Steel and Wire company, the ninety millions of stock of which had to be considered in organizing the new company. The American Steel and Wire company had for its assets the stock or the actual property of the following companies: American Steel and Wire company, plants at Anderson, Indiana; De Kalb, Illinois; Evanston, Illinois; Joliet, Illinois; St. Louis, Missouri; Cleveland, Ohio; Salem, Ohio; Findlay, Ohio; Allentown, Pennsylvania; Beaver Falls, Pennsylvania, and Rankin, Pennsylvania. The Washburn and Moen Manufacturing company, plants at Worcester, Massachusetts; Waukegan, Illinois, and San Francisco, California. The Worcester Wire company, plants at Worcester, Massachusetts. The Cleveland Rolling Mill company, plants at Cleveland, Ohio; Newburg, Ohio; and iron mine property at Negaunee, Michigan. The Indiana Wire Fence company, plant at Crawfordsville, Indiana. The Garden City Wire and Spring company, plant at Chicago. The consolidated Barbed Wire company, plants at Joliet, Illinois, and Lawrence, Kansas. The Laidlaw Bale Tie company, plant at Joliet, Illinois. The Cincinnati Barb Wire Fence company, plant at Cincinnati. The Union Rolling Mill company, plant at Cleveland, Ohio.

The Portage Iron company, plant at Duncansville, Pennsylvania. The Newburg Wire and Nail company, plant at Newburg, New York. The Alleghany Furnace company, plant at Alleghany, Pennsylvania. The Pittsburg Wire company, plant at Braddock, Pennsylvania. The Shenango Valley Steel company, plant at Newcastle, Pennsylvania. Oliver Wire company, plant at Pittsburg, Pennsylvania. Oliver and Snyder Steel company, plant at Pittsburg, Pennsylvania. Shoenberger Steel company, plant at Pittsburg, Pennsylvania, and coal, lead and coke ovens in Westmoreland and Fayette counties. The Puget Sound Wire, Nail and Steel company, plant at Everett, Washington. The Edgar Zinc company, plants at St. Louis, Missouri, and Cherryvale, Kansas. The Puritan Coke company, plant and land at Baggaley, Pennsylvania. The Puritan Store company, store at Baggaley, Pennsylvania. The Clark & Sauntry mine at Virginia, Minnesota. The Alpena mine at Virginia, Minnesota. The Cuff Iron company, mine at Iron Mountain, Michigan. The company controlled a large amount of ore and coke and also had a line of steamers on the great lakes for transporting iron ore to the blast furnaces at Cleveland. This property was bought by the Steel and Wire company with the new securities, viz., forty millions of preferred stock and fifty millions of common stock. The preferred stock substantially represented the property, and the common stock the things hoped for.

All the companies in the big new company were more or less like the Steel and Wire company. Each had vast properties, in most cases widely scattered and in each case having enormous issues of stock or stock and bonds outstanding. The task of the organizers of the new concern was to appraise accurately the value of the constituent companies—either on the basis of their earning power or their disturbing power— and then allot to each its due proportion of the new securities. This very difficult task was carried through successfully, and the new securities determined on were three hundred and four million dollars of five per cent gold bonds, five hundred and fifty million dollars seven per cent cumulative preferred stock, and five hundred and fifty million dollars common stock. The bonds went to acquire the bonds and stock of the Carnegie

company.   The application of the new stock was substantially in round millions, as shown in the following table:

Companies.	Stocks Retired— Millions.	New Preferred —Millions.	New Common Million—
Carnegie	66¾	125	125
Federal pfd	53¼	58½	....
Federal com	46½	1¾	50
Steel and Wire pfd	40	47	....
Steel and Wire com	50	....	51¼
National Tube pfd	40	50	....
National Tube com	40	3½	50
National Steel pfd	27	33¾	....
National Steel com	32		40
Tin Plate pfd	18¼	23	....
Tin Plate com	28	5½	35
Steel Hoop pfd	14	14	....
Steel Hoop com	19		19
Sheet Steel pfd	24½	24½	....
Sheet Steel com	24½	....	24½
American Bridge pfd	30½	33½	....
American Bridge com	30½	....	32
Lake Superior Mines	30	38¾	38¾

Mr. Carnegie personally is supposed to have received about two hundred and twenty five millions of the new bonds for his bonds and stock.

The capitalization of the new company as above shown (one billion one hundred million dollars in stock and three hundred and four million dollars in bonds) may instructively be compared with the capitalization of other well known corporations and with other statistics.   This capitalization exceeds the combined capitalization of the following railway companies: The New York Central, Canada Southern, Michigan Central, Chicago and Northwestern, Union Pacific and Southern Pacific.   It exceeds the combined capitalization of the Pennsylvania, Illinois Central, Missouri Pacific and Atchison, Topeka and Santa Fé.   It exceeds the combined capitalization of the New York, New Haven and Hartford, the Central of New Jersey, the Delaware and Hudson, the Delaware, Lackawanna and Western, the Erie, the Chesapeake and Ohio, the Baltimore and Ohio, the Southern railway, and the Central of Georgia.   It exceeds twice the amount of the capital stock of all the national banks in the United States. It is about the same as the average annual supply of currency

in the United States in the past twenty years. It exceeds, after deducting cash in the treasury, the public debt of the United States. The pay roll of the new company amounts to five hundred thousand dollars per day, or one hundred and fifty million dollars per year of three hundred days. It employs two hundred and fifty thousand men, who directly support a million persons more. This is like studying astronomy!

The expectations and opinions of those who have cared to express themselves on the character and future of the great company have been of deep interest. What must be taken as Mr. Morgan's opinion is found in the official announcement signed by his firm and approved by a large number of the interested parties. The announcement says: "Statements furnished to us by officers of the several companies show that the aggregate of the net earnings of the companies for the calendar year 1900 was amply sufficient to pay dividends on both classes of the new stocks, besides making provision for sinking funds and maintenance of properties. It is expected that by the consummation of the proposed arrangement the necessity for large deductions heretofore made on account of expenditures for improvements will be avoided, the amount of earnings applicable to dividends will be substantially increased and greater stability of investment will be assured, without necessarily increasing the prices of manufactured products." This statement undoubtedly met the approval of the great body of the foremost business men of the country whose consent contributed to the consolidation. An interesting, and perhaps a representative, foreign comment appeared in the London Standard as follows: "It is a serious menace to British industry. American users of steel goods will also be squeezed to the last cent short of damage to the trade. It remains to be seen whether the American people will much longer tolerate a fiscal policy which renders such a combination possible. If the trust indulges overmuch in squeezing, the revulsion may carry the nation much further than is dreamed of now in the direction of free trade." To this expression of fear and regret, the New York Herald made this answer: "Foreign observers have not yet got a clear perception of the impelling motive of the combination or its pur-

poses.   It originated not in a desire to crush the steel industry of Great Britain, but to prevent the possible crushing of some of the constituent corporations here.   Its purpose is not to build new plants for increasing the production of iron and steel, but to prevent the erection of new plants and avert the destructive competition this would entail."   The intention ascribed to London bankers to freeze out the new securities, as being hostile to British industry, has yet to be confirmed. It is scarcely probable that British manufacturers can object to a reasonable upholding of rates in this country.   When American factories are fighting one another, they are incidentally fighting the foreign manufacturers.   There are still great steel factories in America outside of the new company. Such companies as the Tennessee Coal and Iron company and the Colorado Fuel and Iron company are still doing business, but they are strong concerns equally interested with the new company in getting fair returns for what they produce.   The suggestion quoted above from the London Standard, that American users of steel will be squeezed to the last cent short of damage to the trade, is not alarming even if true, because damage to the trade will follow instantly any exorbitant charges.   If bridges are permitted to cost too much, wood and stone bridges will be built by both railway companies and the municipalities.   If building frames cost too much, fewer high buildings will be constructed.   If too much is asked for steel cars, wooden ones will continue to be used.   If building materials are charged for excessively, there will be a dearth of new construction.   And so on.   In other words, the new company will make the most money by doing much business at fair rates, rather than small business at extortionate rates.

There seems to be no part of the world which is now not a market for American steel products.   We are building and equipping Russian railways.   The American Bridge company captured the contract against British contractors for bridging the Atbara river in the Soudan.   American cars and locomotives are already doing service in England.   The steel work to be done in the near future in China, Russia, Mexico, South America and Africa is so vast in amount as almost to dwarf the capacity of even this great company.

CENTER OF THE WORLD OF STEEL.

BY WALDON FAWCETT.

[Waldon Fawcett, author; born Salem, Ohio, February 23, 1875; is one of the most popular contributors to newspapers and periodicals on technical matters, writing for the most part as the result of personal investigations; in this connection he has traveled through the United States and Europe collecting information; also syndicates weekly articles on industrial topics to a large syndicate of newspapers. Author of several works on economic and industrial subjects. The article here published is used by arrangement with the Century Magazine.]

The destination of nearly three tons of iron ore in every five that come out of the wonderful Lake Superior country is that awe inspiring beehive of smoke and grime and industry known as the Pittsburg district, the busiest manufacturing center in the world and the very hub of the iron and steel industry. The junction of the Allegheny and Monongahela rivers and the valleys which turn away in every direction constitutes the natural meeting place of the coal and coke, the limestone and ore, which, here manipulated, constitute the thermometer of business.

If the rearing of this greatest of Vulcan's workshops were to be gone through with again in the twentieth century, with the light of experience beating upon the operation, with the present craze for economy of time influencing the iron masters, and with the marvels of modern railroading daily shortening the list of impossibilities, it is possible that the Smoky City would be built nearer Lake Erie; the steel barons might elect to apportion the journeyings of the various commodities more equally by carrying the coal and coke a few hundred miles farther and cutting a few hours from the time required for the trip of the ore from mine to furnace. Now, however, it is highly questionable whether any general migration will ever occur.

The limitations of the Pittsburg district are not clearly defined, but if the reader will follow the schoolboy's old fashioned method of describing a circle on the map with the aid of

a string and a pencil, and will place the pivotal pin on the dot that represents Pittsburg, a radius of one hundred miles in every direction will take in most of the territory where the ironmonger is the supreme sovereign. Andrew Carnegie has defined the steel making center as embraced within a line drawn from Pittsburg to Wheeling, West Virginia; northwestward to Lorain, Ohio, on the shores of Lake Erie; eastward to Cleveland, on the same body of water; and southeastward to Pittsburg.

The very vortex of this creative realm is found, however, in Pittsburg and its immediate environs. In Allegheny county, the division of the state in which Pittsburg is located, there is produced nearly one quarter of all the pig iron turned out in the United States, fully one half of the open hearth or best grade of steel, and virtually two fifths of the nation's aggregate output of steel of all kinds.

A first faint conception of the tremendous, almost inconceivable magnitude of this giant industrial exposition, where above all other places a realization of the majesty of manual labor burns itself into the brain, is gained from a glimpse of the tremendous latent energy that is cast aside in the smoke and steam that hang in a heavy black canopy close above the roofs of the city. Perhaps it is because he understands better than does the stranger the significance of the soot showering clouds that the Pittsburger smiles indulgently upon the visitor who complains because the sun is obscured or because he is unable to enjoy immaculate linen for any length of time.

The iron ore is ready, when it arrives at Pittsburg, to be fed, if desired, directly into the furnaces. There is no necessity for crushers to crumble the rich red mineral in order that it may be readily assimilated. Iron buckets, each capable of holding a ton or more, and traveling at high speed on the long, slender bridges that form the highway for the ore when it is first taken from the lake vessels, carry the raw material from the railroad cars to the capacious wooden storage bins or to the novel elevators which hoist it to the top of the great tubular caldrons where it is to receive its first baptism of fire.

The blast furnace marks the dividing of the ways for the various forms of iron and steel. Everything coming under

the classification of the most useful of metals, whatever is to be its ultimate form and character, emanates from this common source, where are assembled the various substances which combine to give the material its fundamental properties. The ore, fresh from the mines, is poured into the monster flame lined tower along with the fuel—coal or coke or charcoal— and a proportion of limestone designed to form a chemical combination with the impurities in the ore so that they may be eliminated. After tons upon tons of the various ingredients have been dumped into the seething tank, apparently without the slightest effect upon the blinding intensity of the white heat, a blast of hot air, with the power of a hurricane, is forced through the great molten mass. In a remote sense it is the same principle which is employed in the blacksmith's forge. When this gigantic fanning of the flames has been carried on for several hours, the contents of the furnace are drawn off, first the refuse which the fiery bath has concentrated, and then the liquid iron.

Within the last half century the march of progress has witnessed many alterations in the design of the blast furnace itself, and still more changes in the methods governing the handling of its product. So recent have these revolutions been that the steps of advancement may be traced by a glance at the various classes of furnaces yet in service in the vicinity of Pittsburg. There is still in use an example of the old stone furnace, fed by a large force of wood cutters, and numerous indeed are the representatives of that type of structure which, until a few years ago, constituted the approved apparatus for iron melting. To the latter, as to the gigantic furnaces of the present day, the various classes of raw material come by train loads—the ore from the Lake Superior mines, the coke from Connellsville or West Virginia, and the limestone from Ohio.

The mode of operating one of these older furnaces, although it was the accepted method only a few years ago, seems crude enough now. Workmen with shovels transfer the fuel and raw material from the railroad cars to novel iron wheelbarrows which are loaded on a rickety looking elevator that creeps creakingly up the outside of the furnace to the top, a hundred feet in the air. Perched up on this chimney like

structure, with the molten pool directly below—standing above the crater of a volcano, as it were—are workmen whose daily occupation is as dangerous as that of a steeple climber.

The deadliest danger is from the great wave of poisonous gases which rushes up with terrific force whenever the bell, as the top of the furnace is called, is opened to admit a fresh supply of fuel or ore. As a rule, the escaping gases become ignited, and woe betide the unfortunate workman who is tardy in retreating before the sheet of flame that momentarily illuminates the whole country side. At times, however, the gases do not pass off in flame, and the effect upon the workmen of this terrible rush of carbonic acid fumes is very much the same as that which might be expected from an overdose of whisky.

More terrifying even than the menace of the gases is the ever present possibility of an explosion that will toss the massive cover of the furnace into the air. Sometimes this giant lid rises only a few yards and then falls back into place, but there have been instances when it landed on the ground many rods away. Whatever be the force of one of these sudden upheavals of the lava like mass, the laborers on top of the furnace have no warning of its approach, and their chances of life, when flames burst forth as though from a cannon's mouth, constitute the most uncertain of problems.

The new modern furnace, however, has eliminated much of the risk of human life that is involved in tending the ironmonger's kettle under the old plan, and from another standpoint it has shown the way to an immense saving of time and labor in the charging of the huge melting pot. The present day blast furnace may perhaps best be described as an immense iron cylinder bearing a close resemblance to the standpipe of a waterworks system, and mounted on short iron stilts. There are usually two of these furnaces, some distance apart, and extending between them a line of six or eight smaller cylinders. The latter are the stoves wherein is heated the hot air that is blown through the molten mass in the furnace.

The great iron tube reared on end, which, in the eyes

of the spectator, constitutes the blast furnace, is in reality only the outer shell of the monster melting pot. There is a lining of fire brick, and, where the heat is most intense, a sheathing of water helps in the imprisonment. To appease an insatiable appetite, the furnace must be fed every quarter of an hour or so, and one of the larger size structures will, in a working day of ordinary length, eat up from three to four train loads of fuel and iron ore.

The tapping of the furnace is the dramatic feature of attendance upon one of these artificial springs of the manufacturing world. An incision is made low down in the side of the furnace, at the very bottom of the tank of molten iron, and there pours forth in a steady stream, as from a pumping spout, a semi-liquid colorless mass, glowing so fiercely that the unaccustomed eye cannot gaze upon it for long at a time. The dark figures moving about quickly and silently in the gloom—and numerically they seem hopelessly inadequate to cope with such a monster—must think rapidly and act even more hurriedly when once the dam of fire clay has been broken and the rivulet of fire is let loose.

It looks like a sluggish mass, this suddenly descending flood of hot iron, but in reality it moves with insidious rapidity. The close observer might study its course as he would that of a river cutting a new channel; see a shower of sparks thrown up in lieu of spray when it strikes an obstacle; watch it swirl in eddies around some slight obstruction or be turned aside by some large one. To the workmen whose duty it is to hold in subjugation the contents of the quickly emptied measure this is the supreme hour of opportunity, and it is a brief one. The flow from the furnace could be stopped only with difficulty, even in an emergency, and so the toilers must note closely the idiosyncrasies of the traveling iron, and exert all watchfulness that it be guided to the channels into which it is desired to go, or a heavy loss will result.

The men who work at the base of one of these present day iron making vessels face a daily peril fully as great as any that ever came to the laborers up aloft, even in the era of the general use of the old fashioned furnace. Under existing conditions not only must the working men have their

wits about them when the furnace has been tapped and jetties of the searing slime leap out in every direction, but there is ever present the danger that the furnace will break. No vigilance in advance will serve the artisan of the iron world under such circumstances. When the rent has been made and through the gaping wound there pours the white shining fluid that carries destruction, his only chance is to run for his life.

As has been noted before, very little manual labor is utilized nowadays in the feeding of a blast furnace. The cars of coke, ore, and limestone are taken in hand upon their arrival by ponderous machines that upturn them bodily and empty their contents. Instead of the antiquated elevator, with its cargo of wheelbarrows, there are small cars which travel up and down on an incline, and which, upon arrival at the top, are made automatically to dump their contents into the furnace. Even the gases which were formerly the terror of the workmen are saved, to a considerable extent, in the type of furnace now generally constructed. Indeed within the last few years, means have been successfullydevised for converting these gases into electrical power or utilizing their force in the operation of machinery of various kinds. The key note of the whole evolution is economy, and what has been accomplished in this direction may perhaps be best illustrated by citing the fact that where the blast furnace of a decade or so ago produced a ton of iron for each man employed, the present day structure has a proportionate production six times as great.

Even in the disposition of the molten iron a short lapse of time has wrought great improvements. Under the old system the iron which escaped when the furnace was tapped was run into little channels cut in the sand all about the base of the furnace, and there allowed to cool. It hardened, and came out of its earthen bed in the form of pieces called pigs, about three feet long and larger around than a man's arm. Each piece was flat on the bottom, but had a rounded back bearing a slight resemblance to that of a fat pig; hence the name. These pieces of iron were the universal currency of the domain of iron and steel. They might go to the puddling

furnace, where, after the carbon has been burned out in the melting, the mass became wrought or pure iron, and was rolled into bars or plates; or they might go to the foundry, to emerge in some one of the various forms of cast iron; or, finally, their destination might be a steel making plant.

In any case, the pigs had to be remelted, and inasmuch as the frugal iron manufacturer saw in this a waste of time and fuel, he planned to eliminate the making of pigs. The solution was a perfectly simple and natural one. In the present age of industrial operations on a large scale, blast furnaces and converting plants are almost invariably under one management, are located in close proximity, and one is served by the other. There was nothing easier, therefore, than to do away with the old system of consuming hours in allowing iron to cool, and in carrying it perhaps only a few rods, and devoting another interval to bringing it to the molten state again. Substituted for it was the up-to-date method of taking the bubbling porridge of iron from one great kettle and transferring it to another, as a housewife might do in preparing preserves.

A predominant proportion of all the molten harvest from the blast furnaces in the vicinity of Pittsburg goes direct to the immense steel plants that have made this part of the country famous, and for this reason, as well as from the fact that, of all possible transformations the primal metal may undergo, that of steel conversion yields the most useful and most valuable product, it will be found most interesting to follow the metal which takes this route to market. The first stage of this journey—the trip from furnace to steel mill on a train of ladle cars filled almost to overflowing with glowing fluid freight—is perhaps the most wonderful excursion open to an adventure lover in all the world.

Four or five of these bulky, brick lined iron tubs, each capable of holding twenty tons, make up a train, which is drawn by a sturdy little locomotive. In several localities in the vicinity of Pittsburg the molten iron is hauled a distance of more than a mile, and in one case a trip of upward of five miles is necessary. Yet this long jaunt in the open air appears to have not the slightest effect upon the temperature

of the boiling metal. The visitor to a steel plant, taken unawares by the approach of one of these trains of fire, experiences a sensation never likely to be forgotten. A wave of strong, fierce, blistering heat heralds its approach, and remains in the air long after it has passed. The little train proceeds slowly enough, and yet the red tinged mass in each great pail pitches from side to side as though it would slop over each time the car sways. The typical engineer of one of these fiery trains is as interesting a character to watch at work as can be found in all this wonderland. He never takes his eyes from the rocking liquid, and he must be ready, if the waves pitch too high, to slow down very suddenly, or he will lose part of his charge and perhaps work great harm besides.

The furnace iron may go either to a Bessemer or to an open hearth steel plant, these terms indicating the two methods of manufacture in use at the present time. To step into a Bessemer plant in operation is not unlike being set down in the operating stand at a gigantic fireworks display. Tiny meteors, too large to be classed as sparks, fill the entire place, raining upon the flannel garments of the workers. The flying bits of flame that strike hands and face the toilers shake off as a dog might toss aside drops of water, and it is only when some stray bit of burning iron slips down inside a worker's collar that one realizes that these figures silhouetted against the glare are human. Everywhere within the dimly outlined walls rough iron hands suddenly dart out of the gloom and as quickly return to it, lifting and carrying and lowering measures of varied sizes and forms, all alike dripping with flame. There is an occasional burst of light, like that at the discharge of a cannon, but succeeding the darkness so suddenly that it is only blinding.

When the ladles of iron from the furnace arrive at this terminal of the journey, each in turn is lifted from the car by a great crane,—a gaunt arm of iron capable of carrying as much as a thousand men,—and poured into a gigantic kettle known as a mixer, just as a person might pour a pail of water into a tub. There is always the possibility that something will break or a chain slip and an avalanche of liquid metal

be precipitated; so the workmen remain at a discreet distance during this part of the proceedings. The mixer is capable of holding the contents of several of the big ladles, and, indeed, its purpose is to brew into one great mess the product from the various furnaces, making it absolutely uniform in quality. At intervals twoscore tons of the chastened metal are poured into a ladle which carries it to the converter.

The working of the Bessemer converter is the spectacular climax of the most picturesque scene in the entire drama of steel making. The converter itself resembles nothing so much as a gigantic iron egg, hung on trunnions in such a manner as to give it the appearance of being pierced by an axle, upon which, if unrestrained, it might swing round and round. It tips gently and gracefully to receive the huge cupful of molten mixture which a crane serves to it, and after the fiery libation has been poured into its capacious mouth, glides slowly back into a horizontal position. Suddenly with a terrific roar the blast is turned on, and for a time a cyclone of cold air is forced through the converter, on much the same principle as heated air pierces the liquid mass in the blast furnace. In this second chemical purification by intense heat many impurities which had not been driven off in any of the previous processes are eliminated, and a dash of ferromanganese, a metal compound rich in manganese, is added, just as spice is added in cooking.

It is in fixing the limit of time for the blowing through the converter that a boyish looking fellow, perched on a small platform up near the roof, has opportunities dozens of times a day to involve his employers in a loss of thousands of dollars. Wearing great goggles of specially prepared glass, he watches, with the intent gaze of a youngster at his first foot ball game, the flame rushing from the elevated nose of the big retort, which is like the alcohol lamp that jewelers use, magnified many hundreds of times. The visitor, standing upon the elevated platform, sees the pyramid of flame, as it escapes with a hoarse cry from its prison, change in color from red to white and then to the faintest of blues, just as multicolored balls burst from a Roman candle. To the layman the changing tints of the illumination have no sig-

nificance, but not so to the young man, with muscles tense, leaning forward close at hand.

Finally the anxiously awaited shade makes its appearance in the fiery tongues leaping toward the roof, and quick as a flash the operator pulls his lever and swings that, and the blast is shut off. A minute too soon or a minute too late would impair the texture of the metal fabric. The young man intrusted with this responsibility looks no older than many a lad just entering college, yet he is a striking representative of skilled labor in the highest sense of the term, and receives a salary of ten dollars a day.

After the impurities have been blown out of the molten metal, the converter is again lowered, and the fifteen tons of contents are drawn off into ladle buckets, and poured into ingot molds. This marks a distinct step in the transformation of the iron and steel, and before looking into its mysteries it may be well to glance at the second, or open hearth, method of making steel. Under this plan the iron from the blast furnaces, instead of finding its way to a converter, is placed in open hearth furnaces, immense brick structures which resemble nothing so much as the ovens in a bakery and harbor the hottest heat imaginable. Instead of hot air being forced through the molten mass in this instance, dependence is placed upon the inconceivably terrific heat generated by great gas fires beneath the furnaces.

After the liquid steel comes from the Bessemer converter or from the open hearth furnaces, it is poured into molds uniform in size, where it hardens in the form of blocks of steel known as ingots. The ingot molds are iron boxes very much resembling large coffins in size and shape. They stand in a row on a train of pygmy cars, and when, one after another, they have been filled by stopping momentarily under the big ladle of steel, from a hole in the bottom of which a glowing stream flows out, the little train rumbles away, throwing out waves of heat, just as did the group of ladle cars in transit for the blast furnace. After the metal has been allowed to cool somewhat, a heavy iron hand, known as a stripper, drags off the molds, or jackets, leaving red hot blocks of iron, each weighing as much as a dozen men.

The thrusting of the ingot into a bed of flame to reheat it to its old temperature marks the first of the final stages in the evolution of the iron and steel. From this form it may be changed into blooms, or billets, blocks of steel smaller in size; it may be flattened in ponderous presses into armor plate for war vessels; or it may emerge, after endless squeezings between giant rolls, as rails or sheets or bars.

Almost any visitor to one of the great mills where the steel receives the finishing touches which makes it ready for the market is likely to be surprised by the seemingly meager force of men that people the immense structure. Standing at one end of the building, he can scarcely distinguish any of the objects at the other, but under his gaze comes only a vast vista of machinery. The mechanical workers rise from the floor, reach out from the walls, cling to the ceiling. Some are stationary, while others travel at high velocity up and down, round and about the building; yet there is no confusion, no delays or collisions, and, most wonderful of all, the visitor catches only an occasional glimpse of the human hands which control all this vast mechanism, unless he peers into the tiny houses where, inclosed by glass, the operators sit surrounded by levers, like switchmen in their towers.

The most interesting objects in all this mechanicl array are the rolls. Each set, by its appearance, suggests a clothes wringer or the mangle in a laundry, save that there are great, hard, smooth rolls on each side as well as above and below; in other words, pressure is administered from every direction. The ingot is carried to the big flattening machine along a series of revolving rollers, as though it were a board in a moving sidewalk. When the rolls first bite it, and for several trips thereafter, as it squeezes back and forth, the scale which has formed causes each fresh gripping to be heralded by an explosion like the sudden crash of artillery. All the while water is poured upon the rolls in a perfect stream, to keep them from getting overheated, and frequently it splashes on the ribbon of hot metal wriggling through, but apparently without the slightest effect. The drops appear inky black against the fiery

surface, and they roll off with a suggestion of the movement peculiar to quicksilver.

The rail mill presents many pictures that appeal strongly to lovers of the picturesque. Under ordinary circumstances the great strands of iron, each half as long as a city block, slide back and forth smoothly enough between the rolls that are stretching them and pressing them into the required shape, but a tiny obstacle may at any moment turn one of these cables of fire off the beaten track and twist it into a hopeless tangle or wind it like a squirming snake around some unfortunate workman. When the rolling process has been completed, the piece of iron slides along to the great buzz saws, which cut it up into the thirty-foot rails known to the railway traveler. Every time the whirring circular saw clips off one of these lengths, sparks radiate in every direction, as though the biggest pyrotechnical pin wheel ever devised had been suddenly set in motion. When the rail has been cooled, and holes have been drilled in it, it is ready to start for any part of the world. The evolution of bars or beams or sheets from the big steel slabs is gained by the same general method of procedure. It is the size and shape of the grooves in the rolls which determine the form to be ultimately assumed by the steel in their clutches.

The completeness of one of the large modern steel manufactories is one of its finest qualifications. This is strikingly exemplified at Homestead, where is located what is claimed to be the largest single iron and steel making establishment in the world. The buildings, which extend for a mile and a half along the river front, cover acres upon acres of ground, and winding through and around them is a private railway system equipped with seventy locomotives.

STEEL HARDENING METALS.

BY JOSEPH HYDE PRATT.

[Joseph Hyde Pratt, geologist and consulting mining engineer; born Hartford, Conn.,
February 3, 1870; graduated from the Sheffield scientific school of Yale university,
instructor in mineralogy at Yale and later at the University of North Carolina;
state geologist of North Carolina 1897-99; assistant geologist of the United States
geological survey since 1900. Author of about 125 monographs and other articles
on mineralogy and geology mostly contributed to scientific periodicals.]

Chrome ore, or chromite, which contains the metal
chromium, was the first of the minerals containing any of
the steel hardening metals to be mined in the United States
for commercial purposes. The discovery of chrome ore in
this country was made about 1820 by Isaac Tyson, jr., at
Bare Hills, Md., 7 miles north of Baltimore, but the deposit,
being scanty and poor, was soon abandoned. He afterwards
found the mineral at Soldiers Delight, about 15 miles north-
west of Baltimore. In 1827 his attention was attracted by
the appearance in the market place of Baltimore of a man
from back in the country who had in his wagon several lumps
of a heavy black mineral which he was using to keep a barrel
from rolling about in his cart. Upon testing these lumps,
Mr. Tyson found the mineral to be chromite and learned
that it was from Harford county, about 27 miles from Balti-
more.

This was the beginning of chrome mining in this coun-
try and of the chrome industry of the Tysons, which was
later supplemented by manufacturing processes and has
continued down to the present time. In the next year, 1828,
chromite was discovered in Lancaster county, Pa., and the
control of this property was also obtained by Mr. Tyson. It
was afterwards developed into the famous Wood mine, which
has produced about 95,000 tons of chromite.

Chromite mining in Maryland and Pennsylvania contin-
ued for a great many years until many of the deposits or
pockets of chromite were worked out. About the time the
ore began to grow scarce in these states, it was discovered

in California, and for a few years a number of thousands of tons were shipped to Baltimore. When, however, the importation of chrome ore began, about 1884, the chrome mining industry in the United States began to decline. There are known deposits of this mineral in quantity in California and North Carolina, and probably deposits exist in Pennsylvania and Maryland; but, on account of the low price at which the foreign ore can be landed at Baltimore, but a small portion of that used in the United States is mined here. New uses for chromium and the construction of railroads through some of the chrome fields will undoubtedly cause an increase in this industry during the next few years.

The uses of chromite, at present the only source of chromium, can be readily divided into three heads:

1. As a mineral: In the manufacture of bricks as hearth linings for basic, open hearth furnaces, and for water jacket furnaces in copper smelting. For these purposes ores carrying as low as 40 per cent of chromic oxide can be used. It is also probable that chromite can be used to advantage in other furnaces, especially where it is desirable to use fluorspar as a flux.

2. In chromium alloys: Chromite is used to a considerable extent in the preparation of a ferro-chromium alloy. The preparation of this alloy, which is used in the manufacture of armor plates and armor plate piercing projectiles, has become a very important industry. The ferro-nickel alloy is also used in the manufacture of armor plate. It is generally made by the addition of these two alloys of iron to molten steel before it is cast into the ingot; they produce a more or less homogeneous triple alloy.

3. In chromium salts: The first use of chromite was in the preparation of the salts, chromate and bichromate of potash, used in dyeing, tanning, and in the manufacture of pigments; this continues to be its chief use. It was about 1800 that the value of these salts as pigments was discovered, but it was not until the discovery of deposits of chromite that they were used commercially. Some chromium salts are also used for medicinal purposes.

Nickel and cobalt mining in the United States began

probably in 1863 with the opening of the Gap mine, in Lancaster county, Pa. This mine was worked almost continuously and very extensively from 1863 until 1880, and was the only nickel mine then worked on the American continent. With the discovery, however, of the nickel deposits in the Sudbury district, Ontario, Canada, and the moderate prices which prevailed for nickel, work at this Gap mine began to decrease, and about 1891 ceased altogether. It is very probable that there are still good deposits of nickel ore in quantity in this mine and that in the near future it will again become a producer. Since 1891 most of the nickel and cobalt produced in the United States has been at Mine Lamotte, Mo., where it has been obtained as a by-product in lead mining. Attempts were made to mine nickel in North Carolina about 1890, and although the mineral genthite, a nickel silicate, was found in some quantity at a number of places, there was only one place—near Webster, Jackson county—that gave any indication whatever of containing it in commercial quantity. Considerable work was done, but in 1891 the mine was closed and remained so until 1902, when the shafts and drifts were reopened and several carloads of ore were shipped for experimental purposes. There has also been some development of nickel deposits in Oregon and Idaho, and a few tons of ore have been shipped for experimental purposes, but none of the mines can be called producers.

The first general use of nickel commercially was probably in the manufacture of German silver or albata, an alloy of zinc, copper, and nickel. Articles made of iron and plated with nickel have to some extent replaced those made of German silver. Another of the earlier uses of nickel was for coinage, which is yet carried on quite extensively by the United States and many of the European countries. With the introduction of nickel in the manufacture of a special steel the demand for it has largely increased, so that this use of the metal has become the most important. Large quantities of nickel steel are used in the manufacture of armor plates, turrets, propeller shafts, crank shafts, etc. Another use that has received favorable consideration is in the manufacture of nickel steel rails, which were first used

by the Pennsylvania Railroad company, and evidently gave entire satisfacton.

Cobalt is put on the market as the oxide and used almost entirely for coloring glass, porcelain, and similar substances.

The mining of tungsten and molybdenum ores in the United States has become an established industry within the past few years only. Tungsten ores were mined in Colorado and Connecticut, and molybdenum ores in Washington.

Until lately the uses of these metals were few, requiring a comparatively small amount of their salts to satisfy the demand. The salts of tungsten were used as a mordant in dyeing and printing and as fireproof material for wearing apparel, while the principal use of molybdenum was in the manufacture of ammonium molybdate, used by chemists in the determination of phosphoric acid. A small amount of molybdenum salts is used in the preparation of blue carmine or molybdenum blue in the coloring of porcelain. The use, however, of these two metals in the preparation of ferro alloys has led to an increased demand, especially for tungsten, which when added to steel, increases its hardness and toughness, and is believed by some to make it superior for certain purposes to any other manufactured. Tungsten steel is also used in the manufacture of tool steel, spring steel, and sounding plates and wire for pianos, where hardness and strength are especially desired. Molybdenum steel, the beneficial properties of which are similar to those of tungsten, is beginning to be used, but in much smaller quantity.

The only titanium mineral mined for commercial purposes is rutile, a titanium oxide. Titanium was formerly considered one of the very rare metals, but it has now been proved to be one of the commoner elements and is very widely distributed. In the future, besides rutile, the chief commercial source of titanium will be the mineral menaccanite (ilmenite), a titanium iron oxide. Rutile has been produced at Roseland, Nelson county, Va., and in Chester county, Pa. Only a small quantity is required to satisfy the demand, and the product does not amount to much over 100 tons of the crude ore per year.

The uses of rutile are principally in the ceramic industry

for coloring porcelain and in the manufacture of artificial teeth. The titanium oxide will, under favorable conditions, impart a fine yellow color to the porcelain, and it is also capable of being used with other substances to produce secondary colors. The amount of titanium oxide used in the manufacture of artificial teeth is from five tenths of 1 per cent to 2 per cent of the total materials used in making them.

At the present time no titanium is used commercially, as far as known, in the manufacture of titanium steel, although irons have been made containing a considerable percentage of titanium, the result of using ores for their iron contents rather than their titanium. Considerable work has been done, however, experimentally in regard to the use and value of titanium steel and with a great deal of success. It is probable that the introduction of this kind of steel into the general market is not far distant. Its properties of special interest are elasticity, and greater elongation and ductility than ordinary carbon steel.

Uranium and vanadium have been mined in small quantities for a great many years, some of the salts of uranium being used to produce a pure black glaze on porcelain, while other salts are used in the decoration of glass and china ware, giving permanent colors. Vanadium salts are used in the coloring of glass, but principally in the preparation of vanadic acid, as a mordant, for aniline black in dyeing. The use of uranium and vanadium in the manufacture of special steels is still in the experimental stage, but enough has been done to prove that they increase tensile strength.

COAL.

BY EDWARD W. PARKER.

[Edward W. Parker, statistician and geologist; born Port Deposit, Md., June 16, 1860; is statistician of the United States geological survey and was a member of the anthracite coal strike commission of 1902, being chosen as the leading American authority on anthracite coal; he has charge of the investigations into coal and coke industries for the United States census bureau and of the annual reports on these subjects for the United States geological surveys. He is author of many articles on coal and coke for periodicals and encyclopædias.]

The twentieth century found the United States firmly established as the principal coal producer of the world. In 1880 and 1890 the United States was second in coal producing importance, with Great Britain first. In 1870 it was exceeded in production by both Great Britain and Germany.

During the calendar year 1902, there were 27 states and 3 territories which contributed to the coal production of the United States. Of this number there were 5 in each of which the production amounted to less than 100,000 tons; there were four others in which the production was less than 1,000,000 tons; 5 states produced more than 10,000,000 tons each, and 1, Pennsylvania, produced more than 100,000,000 tons.

According to the character of the output, the coal fields of the United States conveniently fell under two great divisions, the anthracite and the bituminous. The areas from which the bulk of the anthracite is obtained are located in the eastern part of Pennsylvania, and ordinarily when reference is made to the anthracite fields of the United States those of eastern Pennsylvania are meant. There are, however, two small areas in the Rocky mountain region where true anthracite is produced in small quantities. One of these areas is in Gunnison county, Colo., the other in Santa Fe county, N. Mex. But, although the product of these two localities is true anthracite, the quantity obtained is so small that it is customary to include it with the bituminous production.

The development of the coal resources of the United

States has been coincident with the rapid advancement of this country in the last few years to the front rank among the industrial nations of the world. Indeed, the country's progress has been due largely to the abundance and cheapness of its mineral fuels, chief among which is coal. Most of this development has taken place during the last two decades and has far exceeded the growth in population, indicating a rapid change from an agricultural to a manufacturing nation. A comparison of the growth in population with the increase in production presents some interesting facts in support of this statement. The ninth census was the first which took separate cognizance of the mining industry, but the United States geological survey has compiled from such records as are available an approximate statement of the annual coal production of the United States from the year when the first anthracite coal was mined in Pennsylvania (1814) to the close of 1902.

At the taking of the census of 1820 the production of coal in this country was less than 500 tons, all of which was Pennsylvania anthracite. The population of the United States in that year was 9,638,453. In 1830, when the population had grown to 12,866,020, the production of coal amounted to 318,072 short tons. At the end of the next decade the population of the United States was 17,069,453, and the coal output was 1,785,574 short tons. The production per capita in that year (1840) was 0.105 ton. This was the first census year in which the coal production amounted to 0.1 ton for each person. In 1850, when the inhabitants numbered 23,191,876, the output of coal mines amounted to only 6,445,-681 short tons, or 0.28 ton for each person. The census of 1860 gave a population of 31,443,321, and the coal production was 16,169,736 short tons, or 0.51 ton per capita. When the ninth census was taken the coal production was still less than 1 ton for each inhabitant, the population being 38,558,371 and the coal production amounting to 36,806,560, or 0.96 ton per capita.

In 1880, when the population had increased to 50,189,209, the production of coal had grown to 76,157,944 short tons, or 1.52 tons per capita. The mining census for the calendar

year 1889 showed a coal production of 141,229,613 short tons
and the population census for the fiscal year ending June 30,
1890, showed a total of 63,069,756, persons, the per capita
production of coal being 2.26 tons.   The twelfth census re-
ported a population of 76,303,387, the United States geological
survey reporting for that year a coal production of 269,684,027
short tons, or 3.53 tons for each inhabitant.

It must be remembered that within the last thirty years
during which the coal production has so markedly outstripped
the growth in population, petroleum and natural gas have
been produced in enormous quantities and to the value of
many millions of dollars annually.   The increased output
of these fuels, however, has been partly offset by a decrease
in the amount of wood used for fuel, but while it is known that
such a decrease has taken place, there are no statistics by
which comparisons can be made.

Annual statistics compiled by the United States geo-
logical survey show that the United States has exceeded Ger-
many's production in every year since and including 1871,
with the exception of the two years 1875 and 1876, and since
and including 1899 has outranked Great Britain.   In 1901
and 1902 the United States exceeded in coal production the
combined output of Great Britain and all its colonies and
dependencies.

The production of anthracite in Pennsylvania during
1902 amounted to 36,940,710 long tons, which was less than
that of 1889 by 3,724,442 long tons.   This decrease was due
solely to the strike in the anthracite region.   The normal
production of the region, according to the statistics com-
piled by the United States geological survey, is between
50,000,000 and 55,000,000 long tons per year.   The suspen-
sion of work for more than five months cut down the produc-
tion to about 60 per cent of the normal output.   It must not
be considered, therefore, that the statistics of anthracite pro-
duction presented here represents the normal condition of the
industry.

The total production from the time coal was first mined
in Pennsylvania in 1814 to the close of 1902 is estimated at
a little over 1,500,000,000 short tons, or an average of nearly

PRODUCTION OF COAL PER MINER.
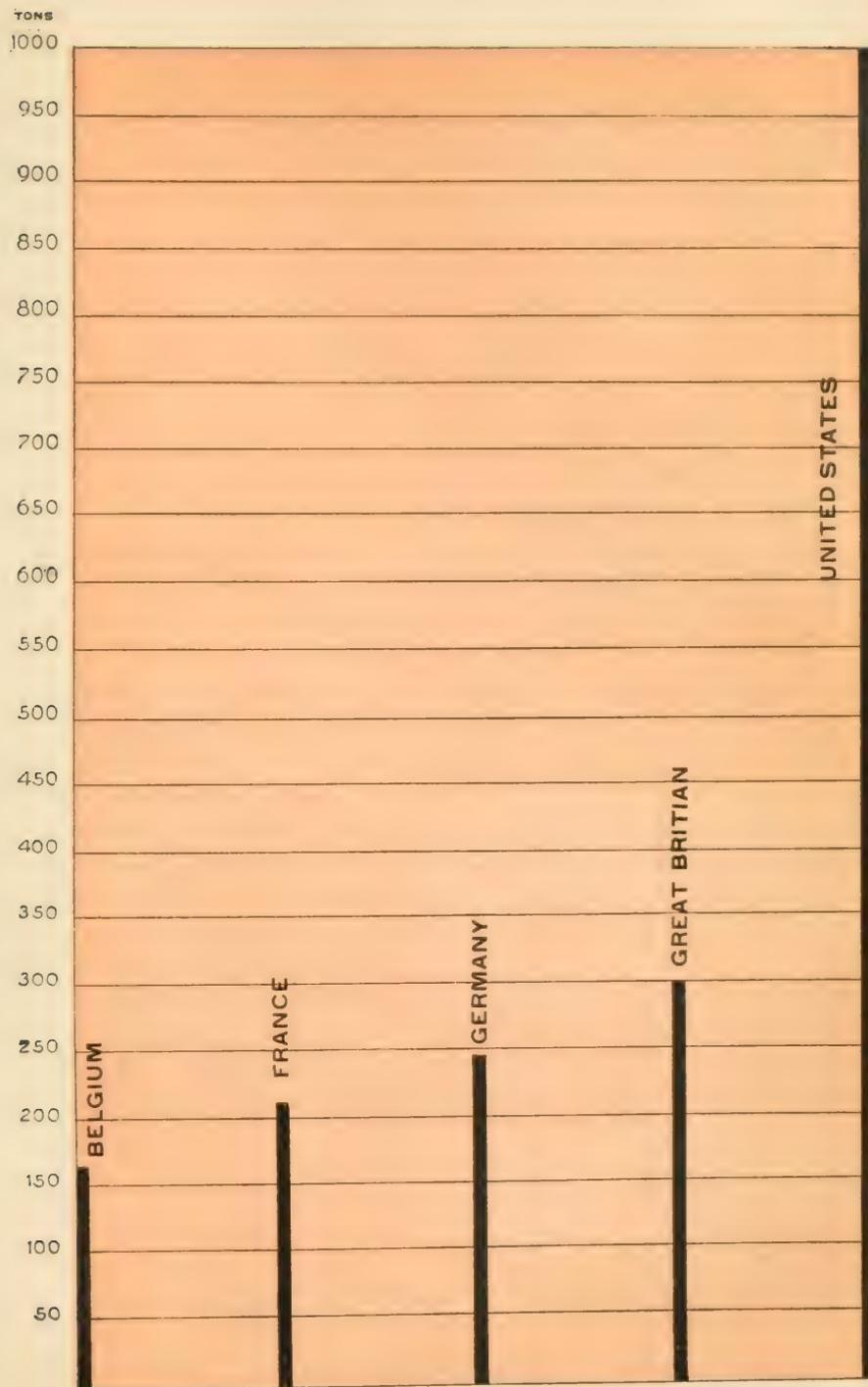
18,000,000 tons a year. During the ten years from 1893 to 1902, inclusive, the average annual production has amounted to a little over 55,000,000 short tons.

The anthracite areas of Pennsylvania are included in the 9 counties of Susquehanna, Lackawanna, Luzerne, Carbon, Schuylkill, Columbia, Northumberland, Dauphin, and Sullivan. The total area of the anthracite fields of Pennsylvania is about 484 square miles.

In a general way the anthracite coal fields may be said to be bounded on the north by the north branch of the Susquehanna river, on the east by the Delaware and Lehigh rivers, and on the west by the Susquehanna river. These rivers together with the Schuylkill, form the drainage outlets for the region. The entire anthracite region embraces a territory of about 3,300 square miles, but less than one sixth of this total area, or about 484 square miles, is underlaid by workable deposits of coal. The productive portion is not in a continuous area, but consists of a number of detached valleys or basins, the general trend of which is about 60° N. to 70° E. They are arranged en échelon, from NE. to SW., for a distance of 120 miles. The greatest width is 30 miles, from Mauch Chunk to Shickshinny, or 50 miles if the Bernice basin in Sullivan county be considered as a portion of the anthracite field proper.

In 1902 the total output of the different varieties of bituminous coal amounted to 260,216,844 short tons, valued at $290,858,483, as compared with 95,629,026 short tons valued at $94,346,809, in 1889, and 42,840,751 short tons, valued at $53,466,958, in 1880.

Though the small mines numbered 826, they furnished but 196,488 tons of coal, or 0.075 per cent of the total bituminous output. They averaged 238 tons per mine, as compared with 53,879 tons, the average production of commercial mines.

THE WORLD'S NEED OF COAL AND THE UNITED STATES' SUPPLY.

BY O. P. AUSTIN.

[Oscar Phelps Austin, chief of the United States bureau of statistics, treasury department, United States; born in Illinois; a writer throughout his business life as reporter, editor, correspondent; author of Uncle Sam's Secrets, Uncle Sam's Soldiers, Colonial Systems of the World, Colonial Administration, Commercial China, Commercial Japan-Commercial India, Commercial Africa, Commercial Central and South America, Submarine Telegraphs of the World, Great Canals of the World, and kindred works.]

Our modern industrial system is so closely dependent upon an adequate supply of mineral fuel that any disturbance of normal conditions in the coal trade reacts immediately upon the general state of industry. Under these circumstances a study of the world's production and consumption of coal and the conditions of the coal trade in this country presents special interest.

One of the most characteristic features of modern industrial development has been the rise of the coal industry. Modera society relies upon coal as the fuel and source of power, and the terms iron age, machine age, and age of steam may all be translated the age of coal.

The rapidity with which the production of coal has increased may be appreciated when we consider the present volume of that production and reflect in how recent a time the production formed but a very small fraction of that quantity. In 1902 the total coal production of the world was 880,000,000 short tons. Until as late a period as 1878 the world's production had never been half so great, being only 292,000,000 metric tons in that year, and not until 1868 had the world's production been as much as a third as large as it is at present. By 1864 the world's production was only 174,000,000 metric tons, or less than 29 per cent of the production of 1896.

The statistics of the world's production for still earlier

but on the basis of the British statistics from 1854, and of periods can not be determined with any pretense of accuracy; estimates for earlier periods, and from such statistics as are obtainable from France, Germany, Belgium, and Austria Hungary, an approximation may be made to the actual production. In 1860 the world's production of coal was about 142,000,000 long or 144,000,000 metric tons, or less than one fourth of the production of 1896, and considerably less than the production of either the United Kingdom or the United States at present.

The production of coal is chiefly in the hands of three nations, the British, the Americans, and the Germans. During the last thirty years, and even earlier, the combined coal output of these three countries, the United Kingdom, the United States, and Germany, has averaged year for year about five sixths of the coal output of the world. Possessing but a tenth (about 10 per cent) of the population of the world, they have produced about eighty three per cent of the mineral fuel, while the remaining 90 per cent of the world's inhabitants have produced only about 17 per cent of the coal; and even if the savage and semi-barbarous nations be disregarded, the immense preponderance of coal production in these countries must be conceded. To this group might be added Belgium, which produces and consumes more coal per capita than any other country except the United Kingdom, but for the fact of its small population, placing it in the second rank of coal producing countries.

While the continued output of these three countries has kept pace with the production of the rest of the world, their relative position has been materially altered. In 1868 the United Kingdom produced over three times as much as either the United States or Germany, the output of these countries being approximately 52, $14\frac{1}{2}$, and $16\frac{1}{2}$ per cent of the world's production respectively. In 1870 the proportion was about the same, although the United States had gained upon Germany as a coal producer. By 1875 the output of the United Kingdom was still considerably greater than the combined production of the United States and Germany, the output of these three countries forming 45, 20,

and 18 per cent of the world's production respectively. The next half decennial period witnessed a remarkable increase in the American production and a corresponding relative decrease in that of Great Britain, the proportion of these countries being 36, 28, and 17 per cent, respectively. This increase was maintained during the last decade, and in 1902 the output of Great Britain and Ireland was less than that of the United States.

These statistics clearly show that the United Kingdom has lost its former pre-eminence as a coal producing power, and that while its production is increasing rapidly, its absolute increase is less than that of the United States, and its relative or proportional increase considerably less than that of either the United States or Germany.

The beginning of coal production in the United States dates back only to the first quarter of the 19th century, although the existence of coal was noticed by the early explorers at the end of the seventeenth and the beginning of the eighteenth century. The Virginia deposits near Richmond, first noticed in 1701, were the first mines to be regularly worked in this country. Mining was begun there about the year 1750, and the coal was sold at Richmond in 1766 for 24 cents per bushel, and at Philadelphia in 1789 for 37 cents per bushel of 76 pounds. In 1822 the amount of coal mined in this region was 48,214 long tons; in 1833, 142,578 long tons. About the year 1820 the development of the anthracite coal regions began. Owing to the fact that the companies which first produced this coal were also building the first canals and railways, the growth of the anthracite coal trade proceeded more rapidly than that of bituminous coal. Until about 1870 the production of anthracite was greater than that of bituminous coal. Thus for the year 1860 the output of bituminous coal is estimated by the United States geological survey at 8,000,000 long tons, while the combined production of the Pennsylvania anthracite regions exceeded 8,500,000 tons, and for the year 1864 the average price of bituminous coal at New York was almost $1 per ton higher than that of anthracite—$7.68 as against $6.75.

It was not until coal began to be used extensively in

the iron industry and the railroads made possible the trans-
portation of coal for longer distance during all parts of the
year that the production of coal, and bituminous coal more
particularly, received its chief impetus. Although in Great
Britain the use of coal for iron smelting dates back to the
eighteenth century, the use of charcoal having been com-
pletely discarded at the beginning of the nineteenth century,
the only fuel used in American blast furnaces until about
1840 was charcoal. This was quite natural, as with the
abundance of large forests the charcoal used for the manu-
facture was relatively cheap, and transportation of charcoal
was less difficult than that of coal. The introduction of
anthracite and bituminous coal in the manufacture of pig
iron created a revolution in the whole iron industry of the
country. Facilities for the manufacture of iron were in-
creased; districts which had been virtually closed to the
manufacture because of a local scarcity of charcoal were now
opened to it; production increased on a large scale, causing
cheapening of prices and growing consumption.

Of the two forms of mineral fuel, anthracite was the
first to be largely used in the iron industry, and it was only
at a comparatively recent period that the relative popu-
larity of the two kinds of fuel for blast furnace used has
been reversed.

The year 1855 marks the passing of charcoal by anthracite
in the production of pig iron, in the year 1869 the use of
bituminous coal overtakes that of charcoal, and in 1875,
also that of anthracite. The decline of anthracite as an
agent in the production of iron becomes still more apparent
if it is borne in mind that ''some of the iron, classed as having
been produced with anthracite and bituminous coal, respec-
tively, was produced with a mixture of this fuel, the quantity
so produced being represented mainly in the anthracite
column. But even on its face the figures show incontestably
that the anthracite coal has been superseded by the cheaper
material. Thus the share of anthracite, which in 1880 was
42 per cent, has fallen to only a little over 10 per cent.

The other great factor which caused the remarkable
growth of the bituminous coal industry was the rapid growth

of the railway system in this country, especially after the civil war. The building of railways, interrupted by the civil war, proceeded, as is well known, at a most rapid rate during the last years of the sixties and the decade beginning with the year 1871. From a little over 35,000 miles in 1865 the number of miles of railroad constructed and operated rose to over 103,000 miles in 1881, and over 170,000 in 1891; i.e., had almost trebled within the sixteen years, and grown fivefold within a quarter of a century. The effect of this development on the eastern and central coal producing states (Pennsylvania, Ohio, Indiana, and Illinois) was twofold. First, by increasing the demand for iron as material for the construction of the railways, thus adding to the existing demand for coal; and, second, by opening opportunities and outlets to the shipment of coal westward, both for use of the railways themselves and the various industries that sprang up with the advent of the railways. Coal constituting the largest item of expenditure in railway transportation, especially in this country, where distances are greater than anywhere in the world, the railways became naturally interested from the very beginning in obtaining their fuel at the cheapest possible price. This explains the close connection of the growth of our railway system with that of the coal industry during the past three decades.

The railways fostered by all possible means the development of adjacent coal regions, the more so that normally coal constitutes the most important article of traffic. Thus, according to the data of the United States geological survey, there were transported in 1903 267,690,560 of tons of coal (59,609,457 of anthracite and 208,081,103 of bituminous) out of a total tonnage of 1,300,000,000 carried; in other words, 20 per cent of the total freight traffic on railways was furnished by coal. The community of interests often changed to identity in cases where the railway companies began to own and operate the mines of the regions through which they passed, thus securing for themselves the double profits of the operator and carrier. At times the railways find it more profitable to transfer the direct control over their mines to a lessee for a number of years, stipulating only the purvey-

ance of a certain amount of coal for their own uses at a certain privileged price.

The impetus given to the mining of coal by the growth of railroads, as was mentioned before, was twofold in its nature. It was partially due to the improved facilities for movement, and consequently its greater cheapness, and secondly to the demand for iron and steel. The growth of the iron and steel industry, however, has acted in many other ways in stimulating a demand for coal. In many departments of industrial activity a revolution has taken place by the substitution of iron and steel for wood and other articles. Thus, in shipbuilding, wooden vessels are rapidly becoming of smaller and smaller importance, while steel and iron vessels are taking their place. In the constructions of buildings a similar development has taken place, and steel and iron have taken the place of other structural materials. The immense strides in the structural steel industry have rendered this form of building material cheaper, especially in view of its durability, than other material for the construction of large buildings.

The number of articles for which iron and steel are now being used is too great to permit of individual instances, but the importance of the entire movement, especially in its effect upon an increased demand for coal, is apparent. Even on the railroads the same development which has taken place from wood to iron and iron to steel in the evolution of the rail is now taking place in the evolution of the car, and iron and steel are completely displacing the wood of the old cars. At present the steel cars, which now average 50 tons capacity, are found to be not only cheaper, in view of their greater durability, but are also far cheaper in operation, owing to the fact that in proportion to their capacity their weight is considerably less than that of the old cars which they superseded.

This development, however, has led not only to a large increase in the demand for coal, but also to a disproportionately large increase in the demand for bituminous coal. In a certain sense, anthracite may be said to have been superseded as completely in the manufacture of iron as has charcoal. Thus, as late as 1880, the amount of iron manufactured from

anthracite was almost as great as that manufactured from bituminous, there being 1,808,000 tons of iron made from anthracite as compared to 1,950,000 tons made from bituminous; while in still earlier periods—in 1855, for instance —there was six times as much iron made from anthracite as from bituminous. This state of affairs, however, has completely changed, especially since the recent great advances in iron and steel manufacture; and while the amount of iron manufactured from anthracite coal has declined to 1,348,000 tons, the amount manufactured from bituminous coal has increased to 12,007,000. This vast increase has naturally led to a rapid increase in the exploitation of the bituminous mines and to a corresponding mining activity in the respective regions.

This change has been largely due to the use of coke. The development of the coking industry in the United States has been remarkable in every sense of the word. Certain coals of the United States, especially those in the Connellsville region in western Pennsylvania, are remarkable for their coking qualities, and the development of the art of coking has been rapid and complete.

The concentration of coal production in the east, while the population is moving so rapidly to the west, has presented the problem of coal transportation, which, owing to the immense bulk of the article, is one of the most difficult of all articles to transport. The movement of coal in this country has mainly been from the east to the west, and the question of transportation from the mines in the middle states, not only westward to the utmost confines of population in the western states, but also, although to a less extent, to New England and the eastern part of Canada, presents difficulties which have taxed to the utmost the transportation systems of the country. The movement westward has been effected both by rail and lake as well as by river.

THE CONNELLSVILLE COKE REGION.

BY FREDERICK EDWARD SAWARD.

It is said that when Mark Twain passed through the Connellsville coke region, he remarked that it looked like hell with the lid off. Other people have, perhaps, not expressed themselves so warmly or so positively, but they have in some way conceived that the Connellsville coke region is a most disagreeable section; in fact, the general opinion, except among those who have ascertained by personal investigation, seems to be that those portions of Fayette and Westmoreland counties that are the seat of the greatest coking operations on the face of the earth are a wild, desolate country, inhabited by a race of beings but little removed from the status of the savage.

The facts are that the Connellsville coke region is one of the most beautiful sections of southwestern Pennsylvania. It is not only rich in the mineral that is now one of the factors, if not the factor, that makes possible the supremacy of a nation, but it is rich agriculturally. Its wide valleys and rolling uplands yield a wealth of grasses, grains, and fruits that is unrivalled by any other section of the United States. It is historic ground—the land of Nemacolin, the Indian warrior; through it passes Braddock's road, near which the unfortunate general was buried after the disastrous reverse to the British arms at Braddock's field, July 9, A. D. 1755. The great national pike from Cumberland to Wheeling, which has been likened unto the Appian way, passes through its heart; and it is watered by the tributaries of the Monongahela and Youghiogheny, supplying it with the finest of water from

the springs of the Alleghenies, which is of the greatest importance in coke making, as it requires large volumes of pure water to produce a first class article of coke.

Within the outlines of this coking coal field there are three important towns, or rather, young cities, viz.: Uniontown, the county seat of Fayette county, Connellsville, and Scottdale. There are also a score or so of smaller places, all of which are to a great extent the result of the development of the coking industry.

The Connellsville coking field proper is of limited area and extends from a point near Latrobe, on the Pennsylvania railroad, in a southwesterly direction through Westmoreland and Fayette counties, a distance of 42 miles, almost to the Virginia line, with an average width of $3\frac{1}{2}$ miles, covering an area of 147 square miles.

There are in operation in this region 89 plants, embracing 20,263 coke ovens, all of which are of the bee hive type, excepting 50 Semet-Solvay ovens, which are being operated by the Dunbar Furnace company, of Dunbar, Pa., for the production of coke and the recovery of the by-products. The ovens in blast produce coke at the rate of 225,000 tons of coke per week, or about 13,000,000 tons per annum.

In the Connellsville coke region proper there are quite a number of new plants under construction. In addition to this, there are a number of plants in what is known as the Klondike region, which is just outside the limits of the Connellsville field proper to the southwest.

The growth of the Connellsville coking industry has been phenomenal. Mr. M. M. Cochran, president of the Washington Coal and Coke company, of Fayette county, Pa., whose extensive operations are located upon a tract of land formerly owned by George Washington, from which fact they take their firm title, and whose father, Mr. Mordecai Cochran, was the real father of the Connellsville coke industry, has given me the following concise statement of its inception:

"Mordecai Cochran, in the year 1843, built two boats on the banks of the Youghiogheny river near Dawson, Fayette county, Pa. During the course of their erection, he made an arrangement with Sample Cochran and James Cochran

by which in consideration of their contributing their labor in the building of the boats in question and in the manufacture of sufficient coke to load those boats, they were to have a one half interest in one boat.

"Mordecai Cochran was a prosperous farmer and owned 300 acres of land, much of which was underlaid with the now famous seam of Connellsville coking coal. He, therefore, had within his own grasp all the facilities for the successful mining of coal, the manufacture of coke and the means of transporting (the Youghiogheny river) the same to a market. The young men, Sample and James Cochran, helped to build the boats in question, mined the coal, manufactured the same into coke and landed it in the boats, and these were floated down the river to Cincinnati, Ohio. Upon the arrival there, Mordecai Cochran went to see Miles Greenwood, the principal iron manufacturer and foundryman of the west. Mr. Greenwood said that he did not need the coke, and seemed to have doubts of its value as an iron smelting fuel; however, Mr. Cochran finally persuaded him to send carts down to the wharf for enough coke to make a test. These carts were loaded with coke free of charge and the test was made immediately. Greenwood was greatly surprised at what he termed the wonderful heat of the strange fuel and the ease with which it melted the pig iron, and he at once purchased the remaining coke at a very fair price. He told Mr. Cochran to go home and make all the coke he could."

This, without a doubt, was the great commission to initiate the manufacture of Connellsville coke and ship it as an article of commerce. It was the formal and complete introduction of it as an iron smelting fuel, and from that time to this there has never been the slightest doubt as to the superiority of Connellsville coke over all other iron smelting fuels. Until Mr. Cochran gave away those cartloads of Connellsville coke its value was unknown.

The seam of Connellsville coal, which is the basis of all this wonderful progress and gratifying prosperity, is one of the most remarkable in the states, if not in the world. It is pre-eminently a coking coal. There is no other seam that can compete with it in cheapness of production. There is

no other coal so regular in formation; so uniform in quality; of so convenient a thickness (8 to 9 feet), or so easily mined. These are not mere statements, but facts—facts that have made Pittsburg the steel center of the world, and facts that in thirty years have been the means of bringing up the output of the blast furnaces of the United States from 30 tons per day to more than 700 tons per day.   The following tables will show the quality of this coal.

In the earlier days of the industry, the incentives for economical and exhaustive mining were not great.   Large areas of the coal lie above water level, much of it with comparatively light cover, and of an inclination that furnished natural drainage and grades in favor of the load haul—a state of affairs presenting few or no difficulties to a mining proposition, and requiring no greater outlay of capital for mine development or expensive openings, timber, etc.   These conditions, together with the fact that Connellsville coal at one time sold at the ridiculously small sum of $12 per acre and for many years remained less than $100 per acre, gave the earlier operators the false idea that it was immaterial whether coal was exhaustively mined or not, and the result was that the mining was done in the crudest way and fully one half of the coal area mined over in the earlier mines was lost.   The mines were often opened up on the single entry plan; the entries were of the most temporary character, and both these and the rooms were driven haphazard; there were no regulations as to width of rooms or pillars, and ventilation and mining engineers were regarded as expensive superfluities.

It was not until extensive operations became a feature of the industry that skill, definite systems of mining, machinery, and mechanical and mining engineers were considered factors at all; even then, if it had not been that coal lands became enhanced in value and the coal seam had to be attacked below water level, with adverse grades, mechanical drainage and ventilation, expensive openings, heavy cover, and immense volumes of water and fire damp to contend with, there would have been no strenuous attempt made to obtain from the seam the greatest possible yield and results.   With these conditions imperatively confronting the operator, a radical

change took place in the operation, methods, and appliances. Coal lands advanced in price from $12.00 per acre to $1,000, and at this day even $1,500 per acre is not thought a prohibitive figure. The drift mines, with their single entries, natural drainage and ventilation, mule motive power, and an output of a hundred tons or so per day, gave way to immense plants, such as the Standard Shaft mine of the H. C. Frick Coke company, at Mount Pleasant, Pa. (the largest coke plant on earth), with its batteries of 908 blazing coke ovens consuming daily over 3,000 tons of coal and turning out daily 125 carloads of the silvery fuel that fears no rival. There, the drift or adit is replaced by the shaft that pierces hundreds of feet vertically the rocky stratum that but a few years ago was thought to seal from man its treasure of black diamonds. The mule is replaced by enormous engines; natural drainage by huge pumps; natural ventilation, by powerful fans; the hand dump, by the steam ram or pusher; and the lard oil torch, by the electric light. Single entries are replaced by double and triple entries, and they and the rooms and pillars are laid out and driven with mechanical precision.

There are many fine operations among the 89 establishments that are marshalled under the generalship of the leaders of this great industry. I shall outline one of the giant plants, the Oliver Coke works of the Oliver & Snyder Steel company, located at Oliver, near Uniontown, Fayette county, Pa.

This plant, with its battery of 708 coke ovens, is the second largest in the world, and it is to a very great extent the result of the energy and foresight of Messrs. H. W. and George T. Oliver, iron and steel manufacturers, of Pittsburg. The mine workings are reached by two shafts, 415 feet and 387 feet, respectively, in depth. The workings proper were developed under the six heading system, i.e., six parallel entries, protected by pillars of coal 600 feet in total width. The mine workings cover an area of 900 acres, which are, in turn, connected together by 46 miles of entries. The total area of the coal field at present tributary to the mine is 1,400 acres leased from the estate of William Thaw, deceased, and more will be added when required. The coal

is hauled from the various gathering points by two endless cables aggregating more than 20,000 feet in length, and a gravity plane 10,000 feet in length; 700,000 gallons of water are pumped daily from the mine workings by the largest Yough pump ever made.

Forty head of horses and mules are kept at all times for use in the workings, and the same are stabled underground in stables built of brick and cement. The main headings of the mine are lighted by electricity, more than 300 incandescent lights being in constant use about the plant. The workings are piped with fresh water supplied by pumps located on the banks of the Youghiogheny river at Connnellsville, nearly 13 miles distant, and thrown over an elevation of nearly 600 feet. More than 300,000 gallons of fresh mountain water are consumed daily upon the premises.

The output of the mine averages 70,000 tons of coal per month, and the capacity of the coke ovens is 500,000 tons per annum. Nearly 500 men are employed in the mine and 350 outside on the coke yards, etc., making a total of 850 men, with a monthly pay roll exceeding $40,000. The cost of the plant is considerably more than $1,000,000.

The Oliver mines have been very difficult to operate, owing to immense volumes of fire damp generated within the workings. Outbursts of fire damp have occurred several times. On one occasion the fire damp reached to the top of the shaft and for twenty-four hours it was impossible to go down the shaft. At another time an outburst filled the mine workings with fire damp for a distance of 500 feet horizontally from the face in less than an hour's time. Three times during the life of this mine has it been necessary to tap the mine workings by means of bore holes from the surface; yet there has never been the slightest accident from fire damp.

Of late years, owing to greater care, better methods, more efficient appliances, and rigid inspection, accidents from fire damp are rare within the confines of the Connellsville seam.

Those accidents, while dreadful of themselves, have been productive of much good, and to them may be traced the present mining laws of the bituminous coal districts of the

state of Pennsylvania. Before these accidents occurred, few dreamed of danger from fire damp in the Connellsville coke region, and I, in common with many other managers, for years went about work with a flaming torch in mines that are now worked exclusively with the locked safety. The accidents occurred mostly in presumed non-gaseous mines. For many years it was presumed to be an established fact that all coal mines above water level were non-gaseous, but some of the greatest explosions of late years throughout the states have occurred in coal mines above water level, though in the Connellsville coke region the fire damp accidents have invariably occurred below water level.

The types of saftey lamp now in use in the Connellsville coke region are as follows, viz.: For examination of the working places by fire bosses, inspectors, etc., the Davy lamp is almost invariably used, though occasionally types of the Clanny lamp are used for that purpose. For the workmen, the Clanny type, bonnetted and unbonnetted, is largely used. The best lamp yet introduced is the Wolf lamp. This lamp has many good features, some of which are as follows: It is always self extinguishing in the presence of fire damp, in explosive mixtures, or in case of being overturned; it is provided with a magnetic lock that cannot be picked; has an igniter by which the lamp can be lighted without opening it, and it gives a good light.

The ventilation of the mines is effected by means of furnaces and fans, principally fans, which are of the Guibal and Capel type.

The hoisting machinery is of the most substantial build, and almost always of the first motion pattern, with differential drums at the shaft mines. At slope mines the machinery is both of the first motion and geared patterns, with various forms of friction clutch. The pumping appliances are operated both by steam and compressed air, and include a variety of direct acting patterns in single, duplex and compound noncondensing types of cylinder and plunger pumps.

Steam is generated principally by two-flue, fire tube and water tube boilers, with a tendency to the general adoption of the latter class with the vertical arrangement of the

tubes, in preference to the horizontal and diagonal align-
ment.   The tippling of the coal is largely done by automatic
or self dumping cages and the steam ram, though at slope
mines the tippling is accomplished principally by means of
drop bottom mine cars and inclined trestling provided with
a large bin placed immediately under the mine car tracks.
The coal mining is all done by pick work; as yet, machines
have failed to perform this work satisfactorily.   The coal
is very easily mined by hand.

The hauling of coal underground is largely done by some
form of tail rope or endless rope haulage.   At the Leisenring
shaft No. 1 of the H. C. Frick Coke company, compressed
air locomotives have been installed at a cost exceeding $20,000
and are giving most excellent results.   These locomotives
are of the high pressure type, using air at a pressure
of 500 pounds per square inch (manipulated by a form of
reducing valve, and are very compact—quite a contrast to,
and a great improvement over, the cumbersome low pressure
machine in use at mines heretofore.

Electricity is largely in use for stationary lights at the
principal points about the mines and in the various buildings.

The mine workings are now developed by the two, three,
four, five and six entry systems of mining.   All the working
places are driven on sights, i.e., on lines given by the mining
engineer.   In some of the mines the retreating system of
working has been adopted, and the aim is now to recover
all the coal as nearly as possible.   The most skillful mining
engineering talent is employed, and coal mining is rapidly
becoming a science instead of a rule of thumb operation.
The cost sheet is no longer considered by its monthly showing,
as in former days, but by its relation to the general result
during the whole term of the operation.

The coal is all coked in the beehive type of coke oven,
and the coke is drawn by hand, as machinery has so far failed
to perform that operation either as satisfactorily or as cheaply
as the human coke drawer.   The coal is run directly from
large bins, located near the mouth of the mines, into hopper
shaped cars known as larries, and these, in turn, are hauled
to the coke ovens by locomotives or some form of rope

haulage, and the coal is spouted out of the larries directly into the ovens. The levelling of the coal in the ovens (a very important operation) is performed by hand work; in fact, there are very few mechanical appliances in use about the coke yards.

In closing, I cannot refrain from referring to the one man, who, of all others, has been the great factor in the building up of the Connellsville coke industry, which represents an investment of over $100,000,000 and furnishes direct employment to 20,000 men. I have written of Mr. Mordecai Cochran as being the father of this industry, but Mr. H. C. Frick, of the H. C. Frick Coke company, has been more —but for the physical incongruity of the term I would say that he was the mother, for it is he who has taken it into his arms an infant, as it were, giving employment to but a few hundred men, and nursed it year after year until it grew into the giant of to-day, employing over 20,000 workers— workers who are a credit to any land, for the workers of the Connellsville coke region are not by any means the degraded class of people that misinformed persons sometimes intimate they are. As a rule, a more orderly, industrious, and peaceable lot of men cannot be found in any industry. It is true there have been strikes and riots, but these never originated among the great majority; neither were they countenanced by them, but came from a few would-be dictators that no longer have a semblance of influence in the district.

GOLD AND SILVER MINING.

BY ISAAC A. HOURWICH.

[Isaac A. Hourwich, statistician and geologist; born Wilno, Russia, April 27, 1860; graduated from the classical gymnasium; studied at the University of St. Petersburg, Russia, 1877-9; and later at Columbia university; is at present statistical expert in the census bureau of the United States and has made extensive investigations into the condition of the mining industry, especially gold, silver, copper, lead and zinc; has written many articles on these subjects in which he is a recognized authority and also is author of The Economics of the Russian Village.]

The production of gold and silver antedates the dawn of written history. The search for the precious metals prompted the discovery of new continents and stimulated the efforts of the alchemists, thus indirectly leading to the development of scientific chemistry. Yet it is only since the beginning of gold mining in English speaking countries, at about the middle of the nineteenth century, that any progress in mining methods can be recorded. And even to-day, notwithstanding the technical advance of the last half century, mining methods of primitive man can be observed in actual operation in some parts of the United States.

The earliest form of gold mining is the working of alluvial mines or placers, where the gold has been reduced by the operation of the forces of nature to fine dust mixed with gravel. The work left for the miner is to separate by washing the particles of gold from the surrounding mass of sand and gravel. The final product of the mine is gold.

The pioneers of gold mining in the United States had no experience to guide them but that of the Latin-American countries. The results accomplished by the Spaniards were extremely meager. Mr. T. Wain-Morgan Draper, writing in the Engineering and Mining Journal concerning the gold deposits in Ecuador and Colombia, cites the example of one property which was worked extensively with numerous slaves for over one hundred years. A careful examination and measurement of the work accomplished shows that half a dozen 4-inch giants would do as much in one year's time. No such results could be accomplished by the Spaniards

with their tiny reservoirs, which, when filled with rain water, were turned loose to wash the gravel down a rock sluice.

The beginning of gold mining in the United States dates back to the first quarter of the nineteenth century, when some placer mining was done in North Carolina and Georgia The settlers worked at odd moments singly or in small gangs, giving to mining such time as they could spare from other occupations. The workings were largely executed by slave labor and were confined chiefly to surface mining.

The gold pan, the long tom, the rocker, and the pick and shovel constituted the miner's outfit. These simple methods still survive wherever placers are worked by miners with practically no capital and without hired labor. It may be fairly estimated that most of the placer gold mined in the western states and Alaska is produced in this time honored fashion. The following extract, descriptive of placer mining as it was conducted in Alaska as late as 1900, is quoted from an official report:

The mining on the beach is the simplest operation possible, a rocker being all that is required in addition to a shovel and a pick and a good, strong back. The dirt is shoveled up and thrown onto a coarse screen, which removes the larger stones and trash, the latter derived from the driftwood, etc., from the sea. The fine dirt passes over a series of riffles, which are small obstructions, and is finally washed off, leaving the heavy gold. In some cases the tailings pass over a small piece of carpet or burlap, in other cases an amalgamated silver plate is used; but in each case the object is the same, viz., to catch the fine gold. The heavy particles of gold are caught in the riffles, while the fine either amalgamates or is retained by the carpet, while the lighter material or tailings is washed away.

Soon after the discovery of gold in California, however, the inventive genius of the American miner devised a simple but effective way of working placer mines. The first hydraulic apparatus for working placer mines was introduced in the spring of 1852 by a miner, whose name is not remembered, at his claim at Yankee Jim, Placer county, California.

This machine was very simple. From a small ditch

on the hillside a flume was built toward the ravine, where the mine was opened. The flume gained height above the ground as the ravine was approached, until finally a head, or vertical height, of 40 feet was reached. At this point the water was discharged into a barrel, from the bottom of which depended a hose, about 6 inches in diameter, made of common cowhide, and ending in a tin tube about 4 feet long, the latter tapering down to a final opening or nozzle of 1 inch. This was the first hydraulic apparatus in California, simple in design, dwarfish in size, yet destined to grow out of its insignificance into a giant powerful enough to move mountains from their foundations. The news spread among the miners, the wonderful practicability of the new invention was at once acknowledged, and, wherever circumstances permitted, a hydraulic, the name adopted for the novel apparatus, was rigged.

The original idea was much improved upon in the course of time, and the hydraulic method proved a great labor saver, as compared with the primitive pan, rocker, and sluice. The decline of hydraulic mining within the last twenty years is the outcome of a long conflict between the farming and mining interests in California, which has resulted in the débris legislation for the protection of navigable rivers and farming lands. Hydraulic mining requires great space for dumping the masses of earth which are removed from their original position. Formerly, after a bank had been broken up and the gold washed out, the easiest way to get rid of the tailings was to discharge them into the nearest stream. With the extension of hydraulic mining the rivers were soon overfilled with débris, which settled in their beds and was deposited all along their course, causing considerable damage to abutting farm lands. An act of congress was passed in 1893 which requires débris or tailings of all mines operating in the drainage basins of the Sacramento and San Joaquin rivers to be impounded behind dams or other restraining works. This restricts the output, as not nearly as much gravel can be washed in a given time with a given quantity of water as when the débris passed away and took care of itself without having to be impounded.

When the first surface diggings were exhausted, atten-

WORLD'S PRODUCTION OF GOLD
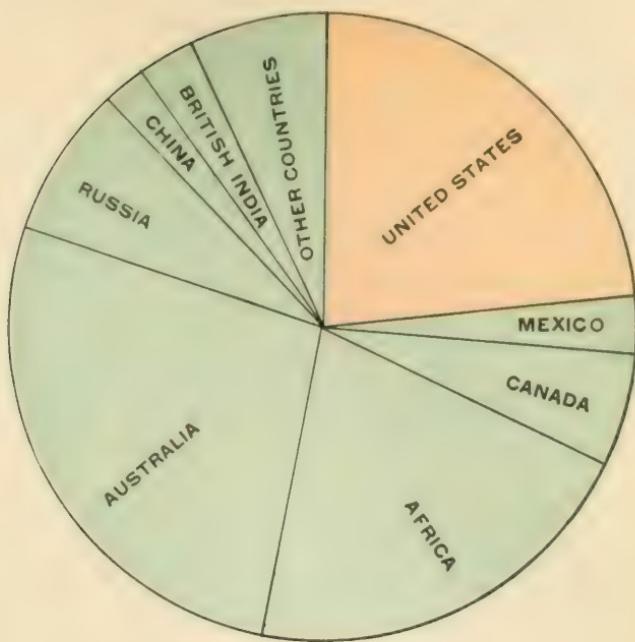
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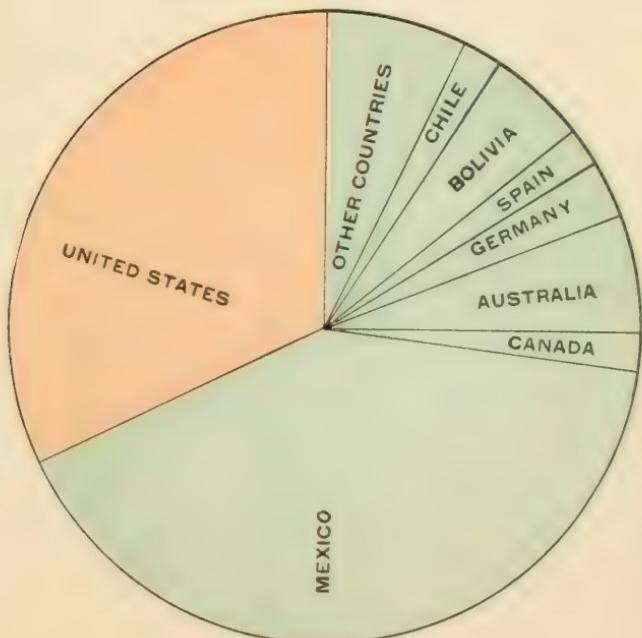
tion was turned to deep lying auriferous gravels which are overlaid by a capping of volcanic rock or by a deep stratum of barren gravel. These mines are worked by drifting.

The drifting process consists in running long tunnels under the lava capped divides and tapping the ancient river channels, receiving only the lower and richer stratum of gravel and then washing it, or, if cemented, crushing it under light stamps. In some places shafts 70 or 80 feet deep are sunk, and the lower gravel near bed rock is breasted out, hoisted, and washed. The larger drift mines are usually opened by tunnels.

A quarter of a century ago the gravel was shoveled into hand cars and wheeled out to the mouth of the tunnel. Since that time the larger drift mines in following the gravel channel have continued to extend their tunnels until they are miles in length.

To-day the gravel is removed by trains of cars operated by compressed air or electricity, the power being generated by the water flowing from the tunnels. The tunnels and drifts are lighted by electricity. A material saving in cost is made by the use of these compressed air or electric power plants. The loaded cars run out on the grade, and the power is used for hauling them back to the breasts at or near the foot of the tunnel. The natural drainage of the mines furnishes the power for haulage, lighting, and ventilating.

The latest invention, one which promises to revolutionize the conditions of placer mining, is the dredge. It originated in New Zealand toward the end of the eighties, and after a few years' successful operation in that country was introduced in the United States and is fast gaining ground here. The great advantage of the dredge is that it is not dependent upon a large supply of water, but may be operated miles away from any stream, in the midst of orchard lands. No ditches or reservoirs are necessary, nor need there be a grade or fall for dump. Ground which has lacked suitable fall or water supply may now be mined by means of dredges. The working of these machines is thus described by Mr. Charles G. Yale in a report to the director of the mint on gold mining in California:

"A pit or hole is dug at any likely point, in which is built or launched a hull or scow, on which the dredging machinery is placed. The ordinary surface water soon floats the dredge, which then commences operations. The great endless chain buckets elevate the gravel and earth, which pass through grizzlies to separate the rocks and stones and earth. The rocks are carried by elevating apparatus far to the rear of the dredge, while the auriferous material passes through the gold saving appliances, and the tailings or refuse pass out over the stream. The dredge keeps cutting a new basin for itself to float in as it digs away the bank ahead of it. Of course, the orchard soon disappears under this system, but the underlying gold in the gravel is worth far more than the trees and their product."

Quartz or deep mining developed naturally from alluvial or placer mining. When the deposits in the beds of the streams or higher up the flanks of the hill were exhausted, the miners followed the lines of the mineral yielding gold and finally came to the mother veins. The beginning of quartz mining also belongs to the Spanish and Portuguese period in the history of this continent. At first the method was merely an adaptation of the processes of alluvial mining. The gold deposit was laid bare by an open cut and worked as nearly as possible like a placer mine. The following description of one of these open mines is quoted from an account of a visit made by Mr. Dawson, secretary of the United States legation at Brazil, to the gold mining region of the state of Minas Geraes:

"In Brazil the veins are often of friable material, which can easily be pulverized with the aid of running water, and the country rock on either side of the vein is also frequently of the same character. Where such veins were found, we encountered the ancient open mines that are so characteristic of Brazilian gold mining. It is evident that the old miners knew nothing of the underground mining, and, except in rare instances, their excavations are open to the top. These great gullies were made with the assistance of running water brought from considerable distances in canals carried along a high level of the mountain flank. The water was conducted

to the point where the lower outcrop of the vein began, and as it flowed, with the aid of a pick and shovel, the ore and surrounding material were cut away. This process was continued backward up the hill until the gully became so deep that the débris was unmanageable. The extent of some of these excavations is enormous. One at Sao Joao da Chapada, a few miles south of Diamantina, is 150 feet deep, 1,000 feet wide, and 2,000 feet long.

The mass of material washed down was concentrated in the rudest conceivable manner. Even the use of the sluice was not understood, and in its place the gravel was given its first wash in a canoa. This is merely a level section of the canal in which the gravel and débris is carried down. The water is allowed to fall into this level space over a lip a few inches high, and a workman stirs with a sort of rake the gravel at that point. Below the canoa there is an inclined plane covered with hides laid with the hair up in order to catch the gold that does not sink to the bottom. In addition to the loss of gold inevitable with such a system of washing, the miners labored under the disadvantage of being liable to lose their vein by the falling in of the side rock. And not only did they lose the clue, but it is lost forever. Many of these old mines are undoubtedly still rich, but the veins are so covered up by the débris that their outcrops can not be found and traced. An interesting feature of the larger hillside mines are the mondeas, rectangular masonry reservoirs, 50 to 80 feet square and 10 to 20 feet deep, made to catch and hold material washed down by the canal until it could be conveniently worked. They were necessary where the amount of water was large. In the few instances where the old miners exploited veins for which no water was available, they simply dug a hole, open to the sky, carrying out the mineral and earth upon the heads of slaves."

Gold mining in this primitive fashion was possible only with cheap slave labor. "Not the slightest improvement or advance was made as the years went by," says another observer. "The ruins of an abandoned working in Minas Geraes resemble exactly those of the old world—in Spain, for example, which was to Rome and Carthage what California is to us

to-day." The same is true of the silver mines of Peru and Bolivia. "Until a short time ago all ores and all the water had to be carried from the mines on the backs of the workmen in leather bags."

It goes without saying that the absence of mechanical apparatus for hoisting and pumping did not permit of vein mining except at very shallow depths.

In the United States the pioneer state in vein mining was Georgia, where a few deep mines were operated in the first half of the nineteenth century. The first miners naturally followed the methods which were in vogue in the Latin-American countries, whose experience extended over nearly three centuries. As late as the close of the nineteenth century a specimen of an open mine not very different from its Brazilian prototype was in actual operation in Georgia.

In the early days of quartz mining in the United States the veins were worked to shallow depths only. In New Mexico about forty years ago powder was practically unknown in mining, and the veins could not be worked for more than 50 feet in depth. Water was another source of trouble. Mines were operated by men of small means, capital was scarce, hand pumps only could be afforded, and when the column of water in the pump became too heavy to be lifted by hand, shafts with a good average grade of ore had to be abandoned. A recent example of this character is cited in the report of the geological survey of Georgia, where but a few years ago a mine was abandoned upon reaching the depth of 300 feet, 30 feet below water level, because the operators had to lift with a hand pump an 80 foot column of water in order to keep the shaft free. At the time work ceased the ore was yielding $25 per ton. The progress in the course of the last half century consisted of the introduction of more powerful hoisting and pumping machinery, in the invention of power drills and more effective explosives, in the construction of extensive tunnels for draining the mines, and lately in the application of electric power.

The evolution of mining methods and machinery is best exemplified by the history of the famous Comstock lode in Nevada. The greatest depth reached after more than

twenty years of operation was 3,300 feet. In 1886 work in the lower levels had to be abandoned because of the overpowering flow of water.

Recent improvements in electrical engineering and reduction processes have led to the resumption of mining on the levels which had been submerged for many years. Says R. K. Colcord:

"The ponderous and powerful hoisting and pumping steam machinery plants of the chief mining companies, originally costing $500,000, $750,000, or more apiece, have become dismantled, and electric, up to date machinery of greater power and efficiency is being substituted and installed in their place at comparatively a mere trifle of their original cost. For instance, the electric hoist plant of the Union Consolidated mine cost only about $10,000; Yellow Jacket and Belcher, $12,000 each; and that at the C and C shaft of the Consolidated California and Virginia, the most productive mine of the lode, $16,000. The cost of power furnished, as per contract with the Truckee River General Electric company, is $7 per horsepower, based upon a continuous service and a two minute peak load. In cases of such continuous service this shows an actual saving of 66 per cent. That is, the former rate for steam power was never less than $21 per horsepower."

Technical progress has been facilitated by modern methods of business organization. The pumping association formed for the purpose of pumping the water from the mines of the Leadville basin may be cited by way of illustration.

This association includes nearly all the leasing companies, as well as the owners of territory embraced in the Leadville basin. All mines operating within the association territory bear the cost of pumping in proportion to their output, based on net smelter returns less cost of hauling. By means of counters on these pumps the amount pumped is computed in gallons and charged to the association at the rate of ten cents per 1,000 gallons. Those mines which pump are credited with the amount of water they have raised. Taking the entire district, investigation shows that the flow of water which must be handled is not less than 15,000,000 gallons

a day. Comparing this amount of water with the average daily tonnage of the district for one year, we find that 28.6 tons of water are raised for every ton of ore raised. Careful estimates of the cost of pumping have been compiled and show that it costs 4 cents to pump each ton of water to the surface. Hence, the cost of pumping referred to the ore makes a charge of $1.14 per ton extracted.

The extraction of the metals from the ore was in the early period not differentiated from mining. The most natural method which suggested itself to the human mind for dealing with the gold bearing rock was to reduce it to the same state in which the alluvial gold deposits were found and to separate the disseminated particles of gold from the pulverized mass by the familiar method of washing. These primitive methods are still practiced in the uplands of Mexico.

Amalgamation was the most important discovery inherited by the American miner from his predecessors. In a few cases the ore was crushed in ordinary mortars. At one mine in Maryland the ore, after being crushed in a mortar, was smelted in the neighboring blacksmith shop.

A type of mill generally used in the west in the early days of quartz mining was the Mexican arrastra. As late as 1880 arrastras still outnumbered the stamp mills. The arrastra in its simplest form consists of a circular bed of rock from 6 to 10 feet in diameter, with walls of vertical planks, having an upright pivoted post in the center, from which extend 2 or 4 horizontal arms. Stone drags, weighing usually from 200 to 1,000 pounds each, are attached by ropes or chains to the extremities of the arms, and are slowly drawn around by the rotation of the latter. The depth is usually between 18 and 30 inches. The pavement and drags are of the hardest rock conveniently obtainable. The capacity of an arrastra does not exceed 4 tons per day of twenty-four hours, and usually varies from 1 to 2 tons.

Wooden stamp mills of a very crude type were also known to the Spanish-American miners. A quaint specimen of a homemade stamp mill, fairly representative of its Spanish prototype, was seen at work a few years ago in Georgia. The mine and the mill were worked a few months in the year by

the owner, with the aid of his aged mother. The modern stamp milling process is described as follows:

"Gold stamp milling is that particular process in which a heavy cylindrical body is made to fall upon the ore in such a manner as to crush it, and thereby facilitate a separation between the gold and the valueless minerals by which the gold is incased. The latter weigh less than the former and are removed by the aid of water. The gold is then collected through the agency of mercury, with which it readily forms an alloy or amalgam. From this combination it is finally extracted by the distillation or retorting of the mercury. The mechanism of the stamp acts on principles similar to those underlying the crudest devices used by man. It may be likened to a hammer, of which the shoe is the hammerhead, the stamp stem is the handle, and the die is the anvil. The ore itself has been compared to a nut struck by a hammer, whose blow has separated the valueless shell (the quartz) from the valuable kernel (the gold). Water covers the die and the ore lying upon it. The blow of the falling stamp not only crushes the ore but also causes a violent pulsation of the water. That pulsation becomes converted into an irregular splash against the sides of the mortar. The latter has an opening in front through which the water is discharged, carrying with it the crushed ore. This, called the pulp, spreads itself over tables placed on an incline, which are lined with a metal, usually copper, having an amalgamated surface, such as will arrest the particles of gold and at the same time permit the grains of quartz and other valueless material to pass over it and out of the mill."

With the further progress of gold mining a point was reached where the stamp mill was found inadequate. After the gold bearing veins had been worked to a certain depth usually a few hundred feet, below the surface, the gold would cease to be free milling and, because of the lack of those changes which are due to the penetration of water from the surface, would become refractory, that is, locked up in union with iron pyrite and other materials, so that it would not amalgamate with quicksilver. Many mines were abandoned when the free milling ores gave out. In Gilpin county, Colo.,

this condition was met with very early in its mining history, at levels varying from 100 to 200 feet.

The problem was not fully solved until the eighties, when the process of concentration was introduced. Only rich ores could bear the expense of shipment to distant smelters. As a result, low grade refractory ores which could not be treated by amalgamation were thrown away. The new process of concentration, which reduced the volume of ore to be shipped and treated, was tantamount to a discovery of new gold mines.

The following description of this process is condensed from the report of the Colorado bureau of mines:

"The system of ore dressing known as concentration is one of the most important of all processes applied to the treatment of ores carrying low values in gold, silver, lead, and copper. There is probably no other line of ore dressing so universally used. Notwithstanding the new devices introduced, all are in line with the early and original designs, differing only in the manner of application of principles involved. The theory of concentration is based upon the variable specific gravity of the different minerals. Its application is to separate the various metals, collect those having value, and reject the remainder. A large proportion of the concentrates marketed are derived from the stamp mill tailings. When the value in tailings is in form of pyrite, chalcopyrite, and galena, with gold and silver associated, the ore passes direct from the plates to different patterns of oscillating, or bumping, tables, and the separation made. Where the base minerals occur in comparatively large crystals the stamp battery is often preceded by crusher, rolls, sizing screens, and hartz jigs, the jigs yielding a coarse concentrate, and the tailings from jigs being recrushed in battery over the plates and tables."

The problem of an economical process for the treatment of low grade ores for many years tempted the inventive spirit of mining men. Many processes were devised only to be rejected by experience. The process man became the object of cheap ridicule even in official publications. It was, however, owing to the efforts of one of the multitude of these process men that the cyaniding process was invented, which

gave to the world the wealth of South African gold. At first the new process was met with distrust by practical mining men, but its demonstrated success overcame the doubts of the skeptics. Immense dumps of low grade ore and tailings which had been accumulating since the beginning of mining operations were taken up and reduced by the new process.

Improvement in the processes of extracting the metals from the ore is a potent factor in the development of mining. By the old amalgamation process not more than 70 per cent, and usually not more than 60 per cent, of the gold contents of the ore was saved. With the aid of modern processes more than 90 per cent of the assay contents can be recovered.

The development of the railway system with consequent reduction in freight rates has greatly stimulated the growth of gold and silver mining. When mining operations first commenced in Arizona, some mines were 300 miles away from the nearest railroad, and machinery and supplies were brought in by mule teams. Twenty-five years ago no mine could be worked there which produced ore worth less than $150 per ton. In some mining districts of Colorado, as late as twenty years ago, before they were reached by railways, all ores were subject to freight charges, varying from $50 to $100 per ton. These conditions are now largely a thing of the past. To-day, all important mining camps are crossed by spurs and switches connecting the principal mines with the main railway line. This means a saving of many dollars per ton on all ores shipped, besides a saving on coal and other mine supplies.

The introduction of improved machinery and reduction methods calls for a large investment of capital. The effect of the technical progress has therefore been the gradual displacement of the small operator working his mine without hired labor on the grub stake plan, and the concentration of gold and silver mining under the management of large companies. The movement toward combination, however, has as yet not reached the gold and silver mines. Small properties have here and there been combined into larger ones; still these small aggregations in no way differ from

ordinary incorporated companies and lack the magnitude which is characteristic of a modern industrial combination. In the reduction of ores, on the other hand, combination has made considerable progress.

GOLD AND OTHER RESOURCES OF THE FAR WEST.

BY J. A. LATCHA.

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The Klondyke gold craze strongly reminds us of the tendency of man to rush upon evils that he knows not of, in the consuming desire to secure that which from time immemorial has symbolized prosperity and power. Tragic as was the history of the early days of California and Colorado, the tales of the wild and reckless rush to the bleak and frozen northwest after the world's desire will for many years stir the hearts of Americans.

The fascination of the unknown largely impels men to rush to the desert and to the ice locked gorges of the arctic north after gold, while manifesting little or no interest in the treasures at their feet. Americans, in a general way, know that rich deposits of the most precious of all metals are scattered in profusion within the limits of our states; but few have any distinct knowledge as to where those deposits are, nor of their value to us as a nation. A description of these fields of wealth will here be attempted; but, necessarily, it cannot be exhaustive within the limits of a short article.

For a century gold has been found and mined at a moderate profit in the primary geological formations of the Appalachian mountains in North Carolina, Tennessee, Georgia, and Alabama. Many of the mines of Georgia are especially profitable. But the rich gold finds in the far western states,

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following the discovery of gold in California in 1849, practically began the era of the golden age within the limits of the United States. In the north are the rich deposits of the Black hills of Wyoming and Dakota, and the probably still richer deposits of Helena and other gold camps of Montana. Upon the extreme northwestern boundaries of the United States lie the regions of the Kootenai and Mt. Baker, from which come tales of fabulous riches; and unquestionably, millions of gold will be mined there within the next generation.

In the extreme southwest rich gold fields are now being developed in Arizona, from Callville on the Colorado river southeasterly to the Mongollon and the White mountains at the headwaters of the Salt river. In California gold deposits have been found, and thousands of mines are now profitably operated from the Mojave desert to Mt. Shasta. The so called mother lode, extending from Kern river northward to Feather river, is famous throughout the world as the scene of the labors of the Argonauts of '49, a period never paralleled in the history of gold mining. That territory produced perhaps more nugget gold than any other portion of the globe; and yet the rich placer mines of California were practically exhausted within ten years after the first gold was discovered by Marshall at Sutter. Nevertheless, the steady production of gold from the deep quartz mines on the mother lode furnishes to-day a large percentage of the metal for the world's supply.

The disaster and disappointment suffered by the pioneers of Pike's Peak are of comparatively recent date; and the scenes where gold was vainly sought are well known and held in romantic remembrance by the thousands of tourists to Colorado Springs and Manitou. The history of the fitful fever of the gold hunters of Pike's Peak is in many respects one of the most remarkable in the annals of the craze for gold. Thousands of men dug and delved, revelled and starved, with barren results, on the eastern slope of Pike's Peak, while deposits of fabulous wealth rested, unsuspected and unsought, in the ribs of the earth less than fifteen miles away, on the western slope of that grand and beautiful moun-

tain. This wealth remained undisturbed for a quarter of a century, until discovered by accident, after the swarms of miners at Pike's Peak had sought other fields. The new field, Cripple Creek, is now known throughout the world.

While the locations of some of the rich deposits of gold in this country have been only briefly noted, the regions most remarkable in some respects will be described more in detail.

Central City, a few miles northwest of Denver, has been steadily producing gold for twenty five years; averaging a production of about $500,000 annually. The collapse of silver mines at Leadville resulted in the search for gold at that city; and mines of remarkable richness have been found. These mines produce hundreds of thousands of dollars' worth of gold annually, and promise to continue to be rich producers for many years to come. The unparalleled gold discoveries at Cripple Creek followed closely upon the finds at Leadville. And since the discoveries at Cripple Creek gold has been found, and many mines are being worked, near Telluride and at other points in southwestern Colorado.

The stimulus given to gold prospecting by the discovery of the remarkable deposits in Colorado resulted in finding rich gold and silver deposits at Marysvale, near the center of Utah, to which point the Rio Grande Western railroad was speedily extended. The mines at Deep Creek in Utah, were discovered a few years ago. Almost due south of Deep Creek, near the thirty ninth parallel of latitude and immediately west of the Utah state line, is the gold camp of Osceola, Nevada. Osecola had one of the few exhibits of gold mining operations at the Chicago Columbian exposition. Only recently a mineral deposit rich in gold was discovered at Detroit, a point almost directly east of Osceola, and distant therefrom about fifty miles. Since the opening of the mines at Detroit, valuable finds have been made within a radius of thirty miles of that camp.

Pioche, in southeastern Nevada, about thirty miles west of the Utah line, is one of the pioneer mining camps of Nevada. Like the famous Comstock lode of Virginia City, Pioche has produced gold and silver in almost equal proportions; but the gold alone would pay for operating that

old and reliable mine. For more than twenty years a steady stream of gold and silver has poured out of that camp.

From Pioche to Bodie, California, lies one of the most interesting and valuable mineral fields in the world, and yet, strange to say, until ten years ago, one of the most neglected.

The marvellous wealth of the Bonanza mines of the Comstock lode at Virginia City has become a household word. But the wealth of the Comstock lode was not known when the Washoe mania seized men,—a mania probably as marked as any ever known to the mining world,—and the memories of the hardships and orgies of those mad days is almost as sacred to old miners as is that of '49. Eureka, a later find, about sixty miles east of Washoe,—or Austin, as it is now called,—has developed better staying qualities than Washoe, owing to the large percentage of gold mixed with the silver. For the same reason many of the mines near Eureka continue to be paying properties.

The overflow of hardy and reckless miners from Washoe spread over every mountain, cañon, and plain of Nevada from Washoe to Pioche. Numerous mines rich in gold and silver were found, and for a time were profitably worked; but unfortunately the gold was so combined with base metals that it could not be separated by the methods known and practiced twenty seven years ago. In mining parlance, almost all those ores are refractory. As a result of the lack of knowledge by the miners of the arts of reducing ores, abandoned shafts and smelters are now to be seen throughout that vast territory,—at Grant Camp, near Freiburg, at Kawich valley, at Reveille, at San Antonio, at Hot Springs, at Gold Peak, at Marietta, at Columbus, and at Candelara. At all these points, and at many others, were mines assaying from $20 to $50 per ton in gold. As that metal, however, could not be separated from the base ores, all that country was given over for years to desolation and anathemas.

No gold or silver has been found in the valley of the Humboldt; but far north of the Central Pacific railway some rich deposits have been found during the last few years. The rich ore deposits of Nevada lie almost on a direct line from Pioche to Bodie. It is evident from the facts stated, that a greater

mother lode actually exists in Nevada almost similar to the one so famous in California. The former rests upon the slopes of the divide extending from near Sevier lake in Utah to Mono lake in California. The waters of that divide run north to the Humboldt Valley and south to the Colorado river, Death valley, and Owen's lake. The demolition and denudation of that divide, due to the attrition of water through the ages, have exposed the metal deposits described. The continuous chain of deposits of gold and silver on that great Nevada divide has never, to the knowledge of the writer, been noted. If a systematic exploration of that great east and west divide should be made, surprising results would follow.

Since the discovery of the gold deposits of Leadville and of Cripple Creek, and with the possession of new methods of treating refractory ores, old miners have renewed operations on the condemned and abandoned Golconda of Nevada, with remarkable results. The ores at Leadville and Cripple Creek are mostly of the same character as those of the abandoned mines in Nevada. But, with the cyanide process now employed, mines assaying from $15 to $25 per ton in gold ore are worked at a profit in the Colorado camps. The discovery of the cyanide process will revolutionize the mining situation in Nevada. The fabulously rich gold deposits at Ferguson, or the Monkey Wrench district, in southern Nevada, have been found during the last twelve years. Equally valuable finds have been made within the last ten years at a point about one hundred miles west of Hyko. These ores assay from $50 to $40,000 per ton in gold; and every dollar can be easily extracted by the cyanide process.

It will doubtless be asked why those rich mines are not boomed and why the people are not crazed over them. There are several good reasons for this. In the first place free nuggets of gold are not found; second, the average man lacks faith in a territory abandoned years ago: he is slow to grasp the fact that "circumstances alter cases." "Once condemned, always condemned," is the dogma of most men in business, as in morals. The third reason is that the fuel for working the mines and the smelters in southern Nevada is such that eastern men generally would spurn the idea of investing money

in the properties. Fagots of sage and other brush constitute the bulk of the fuel used at many of these mines. Even that unsatisfactory fuel costs from $5 to $10 per cord. With a railroad traversing that territory, however, results would ensue in the output of gold which would startle the world.

The mining territory from Pioche to Candelara thus described is wholly in Nevada. Just across the Nevada line, west of Aurora, is Bodie. This California town has been one of the most remarkable gold camps that the world has ever known. It is on the eastern slope of the Sierra Nevada mountains, at an elevation of 9,000 feet, and has, perhaps, produced as much gold as any one mine in California. Northwest of Bodie, also on the eastern slope of the Sierra Nevadas, are Markleville and other mines which contain gold and silver in almost equal proportions; but the cost of supplies has, heretofore, prevented any great development of their deposits. On the western slope of the Sierra Nevada mountains, and almost directly west of Bodie, the heart of the mother lode of California is tapped; one of the richest sections of the great lode being in Calaveras county. This county has been and now is one of the greatest producers of gold in California; and the famous Utica mine in the Angel district of that county is, next to the Stanton mine in Cripple Creek, probably the richest single gold mine in the world.

If a pin be placed at Denver, Colorado, on the map, and another at Stockton, California, and a string be drawn from one to the other, an air line will be marked, passing through the heart of the gold territory described. Slightly to the north of Denver is Central City; and southwest of that city is Cripple Creek; about thirty miles to the north of the string Leadville will be found; in the southwest corner of Colorado will appear Telluride, Rico, and other points where gold is mined; Marysvale in Utah, almost due south of Salt Lake City, will appear to the south of the string; fifty miles to the north of it, near the line between Utah and Nevada, will appear Osceola; Deep Creek lies north of Osceola and on the southern edge of the great desert west of Salt Lake; Detroit and several other rich gold camps are almost due east of Osceola; Pioche lies one hundred miles south of the string;

and the wonderfully rich gold territory of the Monkey Wrench district lies southwest of Pioche.

Now, north and south of the string will appear dotted on the map of Nevada the gold camps of Grant, Freiburg, Reveille, Kawich valley, San Antonio, Gold Peak, Hot Springs, Belleville, Candelara, and numerous others. Almost under the string, in California, we find Bodie, and to the north of it Markleville and other points,—all on the eastern slope of the Sierra Nevada mountains. On the western slope of the great Sierras the string will be almost on the Utica mine, which is located between San Andreas and Sonora. North and south of the Utica mine are hundreds of rich gold mines in profitable operation.

The distance fom Denver to Stockton is about twelve hundred miles. On no portion of the habitable globe is there a region so continuously and enormously rich in gold as the territory described; and yet, notwithstanding this fact, the progressive Yankee has scarcely made a start in opening and developing these riches which have been entombed for millions of years, and which will remain so sepulchered until we awaken to an appreciation of the fact that the states of Colorado, Utah, Nevada, and California bear within their bosoms more wealth than ever was dreamed of by Crœsus.

But the mineral wealth of these states is not confined to gold. Ignoring silver, which will continue to be largely mined as a by-product, they contain riches beyond belief. Colorado and Utah have as fine anthracite coal as Pennsylvania can boast of. They have bituminous coal of first quality for coking and other purposes, exhaustless in quantity. They have iron in immense deposits; Utah, especially in the southwest corner, having mountains of almost pure iron, the like of which, for richness and extent of deposit, exist nowhere else. In Nevada, north of Hyko, is Coal valley,—so named by United States engineers,—where coal of fine quality is said to underlie an extensive territory. Should coal be mined along the line of a railroad traversing that territory, it would be more valuable than the richest gold mine.

Upon coal and iron all modern industry rests. However rich may be the state of Pennsylvania, owing to its coal

and iron, the day will come—and at no distant time—when Colorado, Utah and Nevada, with their gold, silver, coal, and iron, will be the richest territory in the world. But such a wonderful transformation will be possible only when our people shall bend their energies toward opening and developing the resources of these states.

But Colorado, Utah, and Nevada have boundless possibilities of development in addition to their mineral resources, Thirty seven years ago the writer traversed southern California; finding it a sage brush waste, with lands worth, if marketable at all, not more than 50 cents per acre. Los Angeles, the metropolis of southern California, then contained about 4,000 souls. Twelve years ago, a second visit was made to the land of the sun; and a third, eight years ago. A grand transformation had taken place in the appearance and wealth of California. The utilization of water from the mountain streams had made that waste region the home of the rose the lily, and luscious fruits.

The development of Colorado and of Utah began years ago; but the greatest growth has been in the last fifteen years, owing to the opening up of those states by railroads. Abundance of water exists in Colorado; and of many portions of Utah the same is true. In those states irrigation has produced marvellous results. Vegetables are grown there superior to those produced in almost any other portion of the United States. Corn, equal to the best cultivated in Iowa or Kansas, can be grown in the irrigated valleys. Within a few years past, the annual apple festival of Cañon City has become famous throughout the Rocky mountain regions. In very few portions of California can a good peach be grown; but that fruit, equalling the best grown in Delaware, is produced in abundance in Grand River Valley and in other portions of Colorado; and Utah produces just as good. Southern Utah, too, can produce fine grapes, prunes, other fruits, and cotton.

Nevada is not so well supplied with water as are Utah and Colorado; but the high mountain ranges of the southern portion of that state offer ample encouragement to the seeker of the fruits of the soil. Those mountains are the birthplace

of streams, the waters of which, if carefully stored, would irrigate thousands of acres; insuring the production of cotton, grapes, prunes, peaches, apples, pears, and other fruits, as well as grains such as are now grown in Utah and Colorado. All these products would find ready market in the mines, and at high prices.

It will doubtless appear incredible to most readers that a belt of country averaging one hundred miles in width exists in Colorado, Utah, and Nevada, where more of the bounties of nature could be enjoyed, if the country were properly cultivated, than perhaps in any like area on the face of the earth.   Yet such is the fact.

Thirty five years ago sterile mesas and plains covered southern California.   Railroad transportation and irrigation transformed the sage brush plains and valleys of California from barren wastes into beautiful and fruitful gardens.   The same agencies can produce the same results in Colorado, Utah, and Nevada.

As thirty seven years ago the Pacific railways reclaimed the boundless wastes west of Omaha and Kansas City from the buffalo and the Indians, so to-day there are regions in Colorado, Utah, and Nevada, as well as in other of our far western states, where railroads would cause almost as startling changes in the advancement of civilization.   The truth of this would be apparent, should a railroad be built through southern Nevada; furnishing coal for mining and other purposes at a cost of from $5 to $6 per ton, as against present expenditures for fuel practically equalling $50 to $75 per ton.   Such a railroad would reduce the cost of transacting all business throughout that territory to an extent utterly impossible for eastern people to comprehend.

I shall briefly show where one such railroad could be built, insuring the results named.   There are two railroads in operation through Colorado from Denver and Colorado Springs, passing through Cripple Creek and Leadville to Grand Junction.   The western divisions of these railroads have been completed only a few years; but in that time wonders have been accomplished in the cultivation of the soil, and in opening and working mineral deposits in that section.   An ex-

tension of our railroad system should be made from Grand
Junction to Salina Pass, and thence to the town of Salina;
thence to Marysvale; thence to near Cedar City, passing not
far from the great iron deposits of Southern Utah; thence
to a point south of Pioche; thence to near Hyko, passing
Coal Valley; thence south of Reveille; thence to Candelara;
thence to the northern shore of Lake Mono; thence westward
to within about ten miles of Bodie; thence to Mono Pass; thence
down the valley of the Tuolumne river to near the Angel
gold regions of Calaveras county, passing the famous Utica
mine; and thence to Stockton and San Francisco.

Such a railroad would be about nine hundred miles long.
It would cut through immense deposits of bituminous coal
east of Salina Pass, would tap the Marysvale gold and silver
regions, open the greatest iron deposit on our continent,
and would traverse the heart of a territory extending from
Pioche to Bodie, known for a quarter of a century to be rich
in gold, every ounce of which could be reclaimed by the
cyanide process. That road would traverse the finest scenery
in America, via Mono Pass. It would swing around the moun-
tians encircling Mono lake,—one of the most remarkable
sheets of water on the globe; it would present to view the
craters of extinct volcanoes unequalled in North America;
it would pass within ten miles of Yosemite valley, which
could be reached by tourists with ease over good wagon roads;
it would traverse Hetchy-Ketchy valley, which is almost, if
not equally, as grand as the famous Yosemite; and from it
would be seen Mt. Dana and Mt. Lyell, two of the grandest
snow capped peaks of the American continent, each summit
being over 13,500 feet in altitude.

The free gold of the Klondyke region will soon be ex-
hausted, as was the nugget gold of California and Australia.
But the exhaustless golden riches in the quartz formation
of California, Nevada, Utah, and Colorado can be enjoyed
by us for generations after the Klondyke craze shall have
become a terrible memory. The boasted South African gold
deposits cannot compare with the enormous areas containing
gold in our states; extending, as our deposits do, for six hun-
dred miles continuously north and south in California, and for

over twelve hundred miles east and west from Stockton, California, to Denver, Colorado. We can work these mines every day in the year, with every necessary and many of the luxuries of life springing from the soil adjacent to the mines. On no portion of the globe can such bounties be enjoyed as in the territory described. But these boundless resources can be made available to the world only by cheap railroad transportation. This is the primal and underlying factor of modern development.

America contains resources capable of supporting hundreds of millions of people. Happy homes can be assured to generations yet unborn where now are desert wastes, if the cultivation of our fields shall have precedence over all our other efforts at development. Then we can open our mines, and control the seas.

It must be clear from the above mentioned facts, that the enormous resources of our country can be made susceptible of occupancy only by judicious building of railroads. We must gather the waters from our mountain streams and spread them upon the thirsty and grateful soil of our virgin west; enabling the husbandman to repeat in Colorado, Utah, and Nevada the work begun in California. Wealth will flow from every furrow. When our deposits of precious metals are opened throughout those states, great industrial works will cluster around our coal and iron mines; supporting thousands by honest toil.

Capital is timid in enlisting in such enterprises. It is of absolute importance that interdependence and confidence should exist between capital and labor, if our nation is to advance in material growth. It should be the aim of Americans not only to seize and hold a front place in material progress, but to emulate every good work and every high and noble effort of the leading civilized nations. If we adopt this rule of action, labor and capital will meet upon mutually helpful levels; and the capital necessary to enable the people to open and enjoy the riches now buried and useless throughout the great west, will be easily secured. Then the development of our resources will be the most phenomenal in the history of the world; the balance of trade in our favor

as against Europe will be unprecedented; our foreign debts will flow home for cancellation; the millions now annually exported for interest will remain with us; in less than two decades our nation will be the overshadowing creditor of the world; and the finances of all the earth will be controlled within the square mile of New York city overlooked by old Trinity.

PRECIOUS METALS RECOVERED BY CYANIDE PROCESSES.

BY CHARLES E. MUNROE.

[Charles Edward Munroe, head professor of chemistry George Washington university; born Cambridge, Mass., May 24, 1849; educated in the public schools of that city and at the Lawrence scientific school of Harvard university; assistant in chemistry Harvard, 1871-74; professor of chemistry United States naval academy, 1874-86; chemist United States naval torpedo station and war college, 1886-92; expert special agent in charge of chemical industries in the United States census bureau since 1899; has been president of the American Association for the Advancement of Science and of the American Chemical society. Author of over 100 monographs on chemistry and explosives.]

The latest returns show that there are 109 establishments, in 12 different states, using a cyanide process for the extraction of the precious metals from tailings or ores. Of these establishments, 29 cyanide the ore or tailings without other treatment; 27 crush the ore previous to cyaniding; 5 concentrate the ore; 20 combine amalgamation for coarse gold with cyaniding for the finely divided gold; 18 combine concentration and amalgamation with cyaniding; 6 combine smelting, and in some instances amalgamation with cyaniding; and 4 combine chlorination, with and without amalgamation, with cyaniding. In one year these establishments treated 3,089,-673 tons of ore and 199,689 tons of old tailings, or 3,289,362 tons in all, and produced 776,050 fine ounces of gold, valued at $15,972,268, and 1,741,546 fine ounces of silver, valued at $871,878; the products included also 15,000 pounds of copper, valued at $1,670; 741,000 pounds of lead, valued at $12,494; and 8,726 pounds of mercury (recovered from tailings), valued at $5,620, so that the total value of all the products was $16,863,930.

The returns showed directly that of the total output of precious metals 289,305 ounces of gold, valued at $5,947,-888, and 560,872 ounces of silver, valued at $287,614, were extracted from 1,156,643 tons of ore and tailings by means of some cyanide process of recovery. It is estimated that in those operations in which amalgamation, chlorination, smelting, or several of these processes were combined with

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a cyanide process, gold to the value of $2,000,000 and silver to the value of more than $300,000 were recovered by cyanide processes. Hence by the use of such processes there were produced in the United States, in one year, gold with an estimated value of about $8,000,000, and silver with an estimated value of about $600,000.

Gold, when found in situ, is generally in quartz veins intersecting metamorphic rocks, and to some extent in the wall rock adjoining these veins. It may occur either free or combined apparently with tellurium and perhaps selenium, and it is associated with pyrite (iron disulphide), chalcopyrite (copper iron sulphide), galena (lead sulphide), sphalerite (zinc sulphide), mispickel (iron sulph-arsenide), and many other minerals containing sulphur, antimony, bismuth, cobalt, nickel, the platinum group of metals, etc. On exposure to the atmosphere these minerals may undergo chemical changes, whereby many of their constituents are converted into other compounds, while the metallic gold is set free. Atmospheric action also breaks the veinstone into fragments, which are ground to smaller particles by attrition. When suspended in flowing water the superior density of the gold causes the particles, together with the heavier particles of the vein matter, to settle out, through a natural concentrating action, in an obstructed portion of the stream, forming alluvial deposits or placers. Through geologic changes such alluvial deposits may again be formed into rock masses, the gold being found in conglomerate rock cemented together by finely divided material, which may be barren or may itself contain gold. When the gold occurs free in quartz or in a weathered vein, it is called a free milling ore; when it is intimately associated with sulphurets and similar substances, it is called a refractory ore.

Free gold, as found in nature, is never pure, being alloyed to a greater or less degree with silver, copper, and other metals. It occurs in quartz in the form of strings, scales, or plates, and at times in considerable masses of aggregated crystals; the scales are often so small as to be invisible. to the naked eye, so that quartz showing no color and no evidence of gold on panning may yet yield a considerable percentage on assay.

All of the long used methods of securing the gold have been open to criticism with regard to efficiency or economy. Thus, in the working of placers or free milling ores, sometimes the finest particles of gold were not precipitated by the riffle bars or caught on the blankets, but floated away with the slimes; again, the grains of gold were often rusty, or so coated as to refuse to amalgamate when brought in contact with the mercury, and hence, in spite of the use of metallic sodium, or of potassium cyanide and other chemicals, much gold escaped; or the presence of lead, copper, arsenic, antimony, or other substances in the ore caused the mercury to become foul, and therefore unable to take up gold. These, combined with other causes of loss, have led to the estimate that although gold to a value of over $1,000,000,000 has been produced in California since 1848, yet more has been wasted in milling and hydraulic mining by being washed down the rivers and even to the ocean.

Such were the conditions that existed in 1888, when, by tests made on a large scale, it was demonstrated that the cyanide process for the recovery of gold and silver from low grade ores was of practical value and low cost, making it possible to work profitably the large bodies of low grade ore scattered over the earth, and the enormous piles of tailings accumulated around both abandoned and active mines and mills and being continually added to as mining and milling proceeded.

According to Eissler, the fact that gold when in a fine state of division was soluble in cyanide of potassium was already known in the middle ages, when the gilding of metals was carried out by jewelers and alchemists by the use of gold in cyanide solutions. Unless potassium cyanide was at that time made from prussic acid obtained from vegetable sources, it is difficult to reconcile this with the statements made by Watts, by Roscoe and Schorlemmer, and other authorities, that potassium ferrocyanide was discovered by Macquer in 1752 and hydrogen cyanide by Scheele in 1782; for these, particularly the former, are the present sources of potassium cyanide. It has long been known, however, that in the kernels of the bitter almond, peach, apricot, plum,

cherry, and quince, in the blossoms of the peach, sloe, and mountain ash, in the leaves of the peach, cherry laurel, and Portugal laurel, in the young branches of the peach, in the stem bark of the Portugal laurel and mountain ash, and in the roots of the mountain ash, there occur certain glucosides which, through the action of an enzyme in the presence of water, become hydrolyzed, yielding hydrogen cyanide, or prussic acid, as one of the products.

The first instance of an attempt to apply the solvent action of the cyanides to the extraction of precious metals from their ores or other bodies containing them appears in United States patents 61866 and 62776, issued to Dr. Julio H. Rae, of Syracuse, N. Y., on February 5 and March 12, 1867. Dr. Rae claimed the use not only of potassium cyanide as a solvent for the precious metals in the ore, but also of an electric current in precipitating them from the solution, and of rotatory or movable electrodes. This was followed by United States patent 229586, of July 6, 1880, to Thomas C. Clark, of Oakland, Cal., who roasted his ore to a red heat, and placed it, in this condition, in a cold bath containing salt, prussiate of potash, and caustic soda; United States patent 236424, of January 11, 1881, to H. W. Faucett, of St. Louis, Mo., who subjected hot crushed ores, under pressure, to the action of sodium cyanide in solution; and United States patent 244080, of July 12, 1881, to John F. Sanders, of Ogden, Utah, who treated his ore with potassium cyanide and glacial phosphoric acid. But in each of these last three patents the object was to cleanse the gold previous to amalgamation, potassium cyanide having been used for a considerable time, in California and Australia, for removing the coatings from rusty gold in the pan amalgamation process.

The cyanide process acquired commercial value in 1887, when John S. MacArthur and W. Forrest, of Glasgow, Scotland, applied, on October 19, for their English patent covering the use of dilute solutions of cyanides in the extraction of the precious metals. Later they obtained a patent for the use of zinc as a precipitant in a particular state of subdivision.

The commercial value of the cyanide process was demonstrated by tests made on a large scale, with ore from the

New Zealand Crown mine, in June and July, 1888. Commercial success dates from the introduction of the MacArthur-Forrest process, in 1890, in the Witwatersrand gold fields in South Africa, the first cyanide plant in the world for treating tailings having been erected at Johannesburg in April, 1890. In the Witwatersrand alone, at the end of 1891, there were 6 companies treating tailings by the cyanide process; at the end of 1892 there were 22; and at the end of 1893 there were 32, with a record of 143,500 tons per month treated. By the use of this process there were recovered in the Rand 286 ounces of gold in 1890, 34,862 ounces in 1891, 178,688 ounces in 1892, 330,510 ounces in 1893, 714,122 ounces in 1894, 753,490 ounces in 1895, and 703,704 ounces in 1896; the output then increased up to September, 1898, when the commencement of active hostilities in the Boer war interfered with the active working of the mines.

The cyanide process consists in lixiviating the finely powdered ore with a dilute solution of an alkali cyanide, drawing off this solution when charged with the precious metals, and precipitating these metals from the solution. In the patents of MacArthur and Forrest the claims were made for the use of dilute solutions of cyanide (not more than 8 parts of cyanogen to 1,000 parts of water); the employment of caustic alkalies for neutralizing acid ores, prior to their digestion in the cyanide solution; and the use of zinc, preferably in a filiform condition, as a precipitant. The cyanide first used was potassium cyanide, but cyan-salt, which is a mixture of sodium and potassium cyanides, has come into extended use. The tailings, or a charge of ore crushed to the desired fineness, are placed in the leaching vats or tanks and, if acid, given a preliminary treatment with lime or sodium hydroxide, which is generally washed out before further treatment. The ore is then subjected to the action of the cyanide solution, which is usually admitted at the bottom of the leaching vat; after digesting for a length of time, depending on the character of the charge, its fineness, its freedom from slimes, and the strength of the cyanide solution, the solution containing the precious metals is drawn off and the operation repeated.

The leaching or percolation vats vary much in form, dimensions, and construction. Thus they may be of wood, barrel shaped, 22.5 feet in diameter and 4 feet deep, and holding a charge of 30 tons; or of concrete, rectangular, 50 by 40 feet in area and 4 feet deep, and holding 150 tons.

The following facts indicate the wide ranges of variation in methods:

In the Mercur district the ore is covered with solution, which is allowed to stand from thirty minutes to six hours and then drawn off. This operation is repeated from eight to thirty five times. Here the material leached is so coarse that there is no danger of packing. Each operation of covering takes from two to six hours. A few mills cover the pulp with solution, allow it to stand forty eight to ninety six hours, draw it off, and wash. Many of the mills follow the strong solution with a wash of weak solution (one tenth per cent or less). This is in turn followed by a water wash, which flows through the zinc boxes into the weak solution tank and becomes the first wash for the next charge.

In the extraction processes the treatment with cyanide solutions is accomplished by percolation. This method is widely and successfully used, but it has its disadvantages. If the material treated is a clean sand, the solution penetrates throughout the mass, exerting its full solvent effect, and the subsequent draining and washing are easily accomplished. But if the ore contains some kind of rock which is converted by the crushing into a powder that when moistened produces slimes—a formation which is most marked when the rock is of a clayey nature—the presence of these ore slimes in the leaching vats may retard or even prevent percolation, according to their amount and character. In working ores of this kind, the difficulty has been obviated by coarse crushing, but in that case gold is lost, because the solvent can not penetrate through the coarser granules of ore to the inclosed grains of metal. To overcome these defects in the process, resort is had—as in the Pelatan-Clerici process, or in the use of the Aurex sluice—to agitation during exposure to the cyanide solution. Furthermore, since in these processes amalgamation and precipitation are carried on nearly simultaneously

with solution, not only is the coarse gold quickly removed, but the rusty gold is made capable of amalgamation through being cleansed by the action of the cyanide and the electric current, which are employed simultaneously, while the float gold is either amalgamated directly or dissolved and then precipitated. In these processes the precious metals are recovered as amalgams, which need only retorting and melting to be ready for the mint.

A novel method of overcoming the impermeability of slimes is found in the suggestion of Count von Schwerin, who proposes to remove water from wet clay and similar amorphous fine slimes by passing through the mass an electric current, whereby the water is driven to the cathode and the solid particles to the anode by electric endosmosis. The apparatus consists of a wooden vat having for a bottom a brass netting, which forms the cathode; the water being drawn to the netting quickly runs off.

In the MacArthur-Forrest process, the cyanide solution containing the gold and silver is next run into zinc boxes for the precipitation of the precious metals. The zinc boxes, like the leaching vats, vary in character at the different works. A form in common use in the United States is made of 2-inch dressed plank, bolted together and painted with paraffin paint; it is divided into six compartments, 13 by 20 inches in cross section and 20 inches deep, and is provided with a screen about 4 inches above the bottom, on which to place the zinc shavings. About sixty pounds of shavings are required to fill the box. It is provided with an inlet and an outlet pipe, and in the bottom of each compartment is placed a 1-inch pipe closed with a stopcock, through which the slimes are drawn off in cleaning up. The circulation in the zinc box is secured by having the first partition of a compartment extend from the top of the box to within three inches of the bottom, while the second partition extends from the bottom of the box to within two inches of the top. The screen for the zinc shavings is stretched between. The solution from the entrance pipe falls to the bottom of the box, passes under the first partition, rises up through the zinc shavings, flows over the second partition, and thus pro-

ceeds up and down from compartment to compartment until it reaches the exit pipe of the box. The Mercur mill is equipped with long sheet iron boxes having wooded partitions wedged into place; these can easily be removed for cleaning up, the slimes being all brushed together. At the Cripple Creek mill, the slime discharge pipes of the zinc boxes lead from the side of each compartment and discharge the slime into a trough leading to a tank.

When the potassium cyanide solution comes into contact with the gold in the leaching vat, the gold is dissolved, forming potassium aurocyanide.

According to Christy, when the solution of potassium aurocyanide, containing, as it usually does, an excess of potassium cyanide, is brought into contact with the zinc, the reaction may be represented by

$$2\ KAuCy_2 + 3\ Zn + 4\ KCy + 2\ H_2O = 2\ (ZnCy_2 \cdot 2\ KCy) + K_2O_2Zn + 2\ H_2 + 2Au;$$

but in the absence of free potassium cyanide the successive actions taking place may be summed up in the following equation:

$$4\ KAuCy_2 + 4\ Zn + 2\ H_2O = 2\ ZnCy_2 + ZnCy_2 \cdot 2\ KCy + K_2O_2Zn + 2\ H_2 + 2\ Au.$$
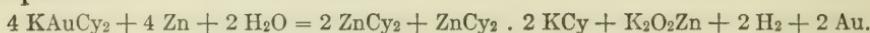
Christy also says: According to the substitution reaction, one atom of zinc replaces two atoms of gold, or 1 ounce of zinc should precipitate 6.2 ounces of gold; whereas, as everyone knows, in practice one ounce of zinc will precipitate only one fifth to one fifteenth of an ounce of gold, or thirty to ninety times less than the amount called for by the reaction by substitution. According to the reactions I have suggested, in the absence of free cyanide of potassium and caustic potash 1 ounce of zinc should precipitate 3.1 ounces of gold; in the presence of a moderate excess of cyanide of potassium it should precipitate 2.06 ounces. The apparent discrepancy that seems still to remain between theory and practice is in reality due to the facts, first, that the free alkali (potash in particular) formed in the solution of the gold, or added to neutralize the free acid in the ore, also dissolves the zinc as potassium zincate; second, that an excess of potassium cyanide dissolves the zinc on its own account, both as the double cyanide and as the zincate of potassium; third, it should also be remembered that water containing dissolved

oxygen attacks metallic zinc quite vigorously, forming hydrate of zinc.

According to Packard, the 60 pounds of zinc shavings required to fill the zinc boxes will precipitate the gold from about 1,500 pounds of 0.2 per cent solution per hour, the solution carrying from 0.1 to 0.8 ounce of gold per ton on entering the zinc box, and from 0.01 to 0.05 ounce on leaving it. The gold in wash waters and weaker solutions is less easily precipitated, a much longer contact with the zinc being required.

On cleaning up, the zinc shavings are washed and the finely powdered portions, called zinc gold slimes, are screened through sieves varying in mesh, at the different mills, from one fourth inch mesh to 60 mesh, the coarse stuff being returned to the zinc box. In this country, where the zinc gold slimes are treated at the mills, they are subjected to the action of an acid, such as sulphuric, which removes much of the zinc and other soluble bodies, and the residues are then washed, dried, fluxed, and melted. A few mills ship these slimes to smelters and refiners, but the difficulty of obtaining a satisfactory sample, and the almost constant wide disagreement between buyer and seller have led many smelters to refuse to handle them.

Precipitants other than filiform zinc are sometimes employed to throw down the gold. Thus, at the Delamar mine, Nevada, the precipitation is by zinc dust, with agitation; Molloy precipitates with sodium or potassium amalgam, Moldenhauer with aluminum, Johnston with pulverized carbon, Christy with cuprous chloride, and De Wilde with cupric sulphate. Precipitation is effected also by electricity, amalgamated copper plates being used in the Pelatan-Clerici process, and thin lead plates as cathodes, with iron anodes, in the Siemens-Halske process.

Electro-deposition processes seem to possess an advantage over zinc precipitation processes in that the presence of caustic soda makes no difference in the result, and that they are as effective with a weak as with a strong solution. Very weak cyanide solutions may therefore be used in the leaching vats. Charles Butters, who has been closely iden-

tified with the development of the cyanide process from its introduction into this country in practical form, and has had extensive professional experience in South Africa, says that in our more modern plants the electrolytic and zinc processes are now used in combination for the recovery of the metal from cyanide solutions. The solution is first cleaned by the electrolytic process. It extracts from 90 to 94 per cent of all the products, including practically all of the copper. About 8 to 9 per cent of the electric box capacity is then filled with zinc, which, aided by the electric current, removes the small quantities of gold and silver remaining. By this combination the zinc is constantly at its best, as everything that would injure the surface of the zinc as a precipitating surface has been eliminated by the previous electrolytic treatment. At Butters' mines, in Salvador, an extraction of about 99 per cent of the values in solution is made on regular monthly runs. This process is used also at Virginia City, Nev., and at Minas Prietas, Mexico.

The methods used in the Witwatersrand have been described recently by John Hays Hammond, as follows:

"The following description applies to the treatment of ores in the pyritic zones. Ores from the upper (oxidized) horizons of the reefs, which constitute but a small percentage of the ores treated, require a slight modification of the process.

"The ground near the mines is level, and does not permit transportation by gravity; consequently the ore must be first elevated into the ore bins at the mill, and the tailings leaving the mill must be elevated for treatment by the cyanide process. This is done either by tailing pumps or, preferably, by tailing wheels. These are from 40 to 50 feet in diameter, and discharge the tailings into a launder, which, with a grade of about 3.5 per cent, carries them to the cyanide works. The auriferous pyrites are, to a large extent, taken out as concentrates by means of Spitzlutten (hydraulic classifier). About 10 per cent of the mill pulp recovered in this way consists of pyrites with coarse sand, a concentration of 10 to 1 being obtained. These concentrates are taken to tanks for separate treatment. From two to three weeks of treatment is required in order to obtain from this material a recovery of

from 90 to 95 per cent of the gold it contains. A solution of about 0.25 to 0.3 per cent of cyanide of potassium is used. After passing over the Spitzlutten the tailings are run to Spitzkasten (pointed boxes), where the heavier sands are allowed to settle, while the lighter material (slimes) overflows, and is carried to the slime works for special treatment. The sands which settle in the Spitzkasten, representing about 70 per cent of the battery pulp, are continuously discharged by pipes leading from the bottom of the box, and are delivered by a hose or by an automatic revolving distributor to settling tanks, into which they are so fed as to be as thoroughly mixed as possible. This separation of the sands from the slimes has to be carefully made, so as to remove all clayey substances, the presence of which would otherwise prevent rapid percolation of the solution and the free access of atmospheric oxygen, which is essential to the solution of gold by cyanide.

"Most of the modern plants have a system of double treatment, the tailings being settled in the settling tanks, when they are treated, after being allowed to drain, with a weak solution of cyanide of potassium. This addition of the cyanide of potassium is made rather for the purpose of saturating the sands with the solution than for thorough leaching, which would be difficult on account of the packing of the sand as they are settled, rendering percolation difficult. After the solution has been drained off, the sands from the settling tanks are discharged into the leaching tanks, placed immediately below the settling tanks, from which they are filled from discharge doors on the bottom of the latter. For a 200-stamp plant 16 steel settling and 16 steel leaching tanks are usually employed. From 3 to 4 settling and leaching tanks are used for the treatment of the Spitzlutten concentrates above described. The settling tanks are usually 40 feet in diameter and 9 feet high. The leaching tanks have the same diameter, but usually a foot less height. The capacity of these tanks is about 400 tons of pulp each.

"In the leaching tanks the pulp is subjected to three treatments with cyanide of potassium. Where the MacArthur-Forrest process is used, the strong solution contains 0.25 per cent, the medium solution 0.2 per cent, and the

weak solution 0.10 per cent of KCy. In the Siemens-Halske process the solutions are weaker, namely, the strong solution, 0.10; medium, 0.02; and weak, 0.01 per cent of KCy.

"The treatment requires from four to seven days. From 130 to 150 tons of solution are usually employed for 100 tons of sand. After being allowed to drain, the sands are discharged through bottom discharge doors into trucks, in which they are removed to residues or tailings heaps. Here, again, elevation is necessary, on account of the flatness of the country, and is usually effected by the endless rope system. These tailings heaps are conspicuous throughout the mining district. By reason of the heavy winds prevailing at certain seasons of the year, they are becoming a great nuisance, and the question of their future disposition is one of the problems for the mining engineer.

"The cyanide solution, after being drawn off from the leaching tanks, is taken to the precipitation boxes. The gold from the strong solution is precipitated in one set and that from the weak solution in another set of boxes. Precipitation is effected by either the MacArthur-Forrest or the Siemens-Halske process.

"In the MacArthur-Forrest process the gold is precipitated by zinc, the solution passing upward through a succession of compartments, in which are placed zinc shavings or filings, resting on a movable tray of coarse screening. About twenty precipitation boxes, 20 feet by 3 feet by 3 feet 9 inches in size, are used. The gold bearing solution is brought into close contact with the zinc, causing the deposition of the gold, partly as a metallic coating on the zinc and partly as gold slimes, which sink to the bottom of the box. As the zinc is gradually dissolved by cyanide more is added.

"Once or twice a month the boxes are emptied, and the gold slimes are treated with dilute sulphuric acid, then dried and melted in crucibles. The dried slimes contain about 15 to 20 per cent of gold, and after fluxing with borax and soda an ingot of 0.750 to 0.800 fineness in gold and 0.100 in silver is obtained. The slag, carrying from 5 to 50 ounces of gold per ton, is usually sold to smelters.

"This precipitation process yields satisfactory results

only with solutions containing more than 0.1 per cent of cyanide, the weaker solutions not being acted upon by zinc. An improvement of the method is the addition of lead to the zinc, whereby the combination of the two metals forms a galvanic couple, which also reacts with weaker solutions, such as are employed, for example, in the treatment of slimes.

"In the Siemens-Halske process the solution flows through compartments very similar to the zinc boxes above described, but the zinc shavings are here replaced with lead strips (0.1 pound per square foot) or shavings hung between iron plates placed vertically and longitudinally in the box, about 4 inches apart. The lead strips are connected with the negative, and the iron plates with the positive, pole of a dynamo, and the solution is thus electrolytically decomposed, the gold being placed on the lead cathode. The iron plates are wrapped in canvas to prevent short circuiting. The current employed is from 2 to 3 volts, giving a current density of about 0.06 amperes per square foot of cathode. Once a month the lead sheets are removed and replaced, and the gold coated lead is melted and cupelled, yielding a bullion of 0.880 fine in gold and 0.100 in silver. The litharge is sold to smelters. The solutions passing through the treatment boxes are collected in tanks, and are made up to a proper strength by adding the necessary KCy.

"The cost of the Siemens-Halske process is slightly greater than that of zinc precipitation, and the percentage of extraction is about the same. But the Siemens-Halske process may be applied to any solution, weak or strong."

From the description of its mode of operation it is evident that the straight cyanide process is readily applicable to free milling ores which are free from mineral substances that would foul the solution or consume the cyanogen salt, and the gold in which is finely divided and so exposed that the cyanide solution may come in intimate contact with it. In old tailings which have been exposed for years to the action of the weather, whereby the sulphurets have been oxidized and the acids and salts formed, dissolved and washed away, there has been found much material ready at hand for immediate treatment in the simplest manner. The prob-

lem is comparatively simple, also, in the case of siliceous gold bearing deposits free from sulphurets, but the ore must be crushed, and in many instances it is more economical to concentrate it than to expose the entire mass to the action of the cyanide solution.   Moreover, even in the case of neutral and otherwise suitable ores, the fine particles of metallic gold may be so enveloped in an impermeable covering—such as iron or aluminum hydroxide—as to necessitate a preliminary treatment, such as roasting, to rupture the envelope.   An example of this kind is found in the ores of the Republic gold mine, Washington, described by T. M. Chatard and Cabell Whitehead.   When coarse gold is mingled with the fine, it is usually more economical to separate the coarse gold by amalgamation than to await the slow acting process of solution.   With tailings in which the sulphurets are but partly decomposed and which still contain ferrous and ferric salts and sulphuric acid, cyaniding may be preceded by washing and neutralization.

The treatment of refractory ores is determined, in each case, by the chemical and physical characteristics of the ore under consideration.   Hence, we find that cyaniding may be combined not only with crushing, roasting, concentration, and amalgamation, but also with smelting and chlorination. In some instances it is most advantageous to separate the ore into fractions, each of which is subjected to a different treatment.   In fact, it is essential to success that the ore should be thoroughly examined by a competent metallurgical chemist before any investment in a plant for treatment by chemical processes is made, and also that the cyaniding process should be under chemical supervision, in order that, by assays of the ore and tailings and by analyses of the ore and the cyanide solutions as they enter and issue from the zinc boxes, and of the solvent during preparation and regeneration, a complete check may be made upon the operation in each of its stages.

It is obvious that the cost of the cyanide process will vary at different plants, according to the variations in the chemical composition and physical structure of the ore treated, in the condition of the ore at the time of treatment—that is, whether it be in the form of sand, or slimes—in the char-

acter of the process and the apparatus used; in the location of the mill with regard to the supply of ore or tailings used; and the source of power, water, materials and labor.

Apart from the phenomenal annual increase in the production of gold during the period from 1841 to 1855, which includes the discoveries of the rich placers of California and Australia, the increase in the world's production during the last decade of the nineteenth century was unprecedented. It was most marked during the period from 1891 to 1895, following the opening of the banket reef of the Rand and the introduction of the cyanide processes, but it was continuous throughout the decade, except during the period of the Boer war. It is true that the use of the cyanide process is only one of several causes contributing to this result, but that it is an important one is indicated by the fact that the returns for the last census show that the amount of gold recovered by the use of the cyanide process in the United States in 1902 exceeded that won throughout the whole world by all existing means during any year of our record up to 1661, and probably up to 1701.

THE INFLOW OF GOLD.

BY ELLIS H. ROBERTS.

[Ellis H. Roberts, treasurer of United States; born, Utica, N. Y., September 30, 1827; graduated from Yale, 1850; principal Utica free academy, 1851-59; editor of the Utica Herald, 1851-80; member of New York legislature, 1866; member of congress, 1871-5; assistant treasurer of the United States, 1889-93; president Franklin National bank, New York, 1893-7; treasurer of United States since 1897.]

The discovery of gold in California lifted the production of the yellow metal in the United States from $889,000 in 1847, to $60,000,000 in 1852, and from 1850 to 1860, produced an average of $55,000,000 a year. The event marks an epoch. In twenty one of each of the years since, our mines have turned out less than $40,000,000 while in 1902 they gave $80,000,000. Out of this situation pregnant problems arise which call for thought.

In the United States at the beginning of the month of October, 1903, the gold in the stock of money was $1,277,-362,657; the amount in circulation in coin and certificates was $1,016,648,693, while in the treasury was $654,811,716. If this stock of gold could be gathered in a solid mass, we should have a cube of nearly sixteen feet, weighing 2,354 tons and requiring 147 freight cars to move it. Were all coined into eagles and placed edge to edge, the line would be 2,116.84 miles long, say from New York to sixty miles west of Colorado Springs. Of the world's production in 1902, amounting to $290,000,000, the United States furnished $80,000,000.

In gold in stock, in circulation and in official holdings our country surpasses every other nation. The stock of Great Britain is $528,000,000, so that ours is double. The increase in five years here has been $376,021,387. In that period Great Britain has added $90,000,000; France, 137,-700,000; Germany, $95,000,000; Austria-Hungary, $55,300,-000, while Russia lost $10,400,000 and in several other countries there has been a reduction. In all of Europe the total

VARIATION OF COMMERCIAL RATIO OF SILVER TO GOLD SINCE 1700
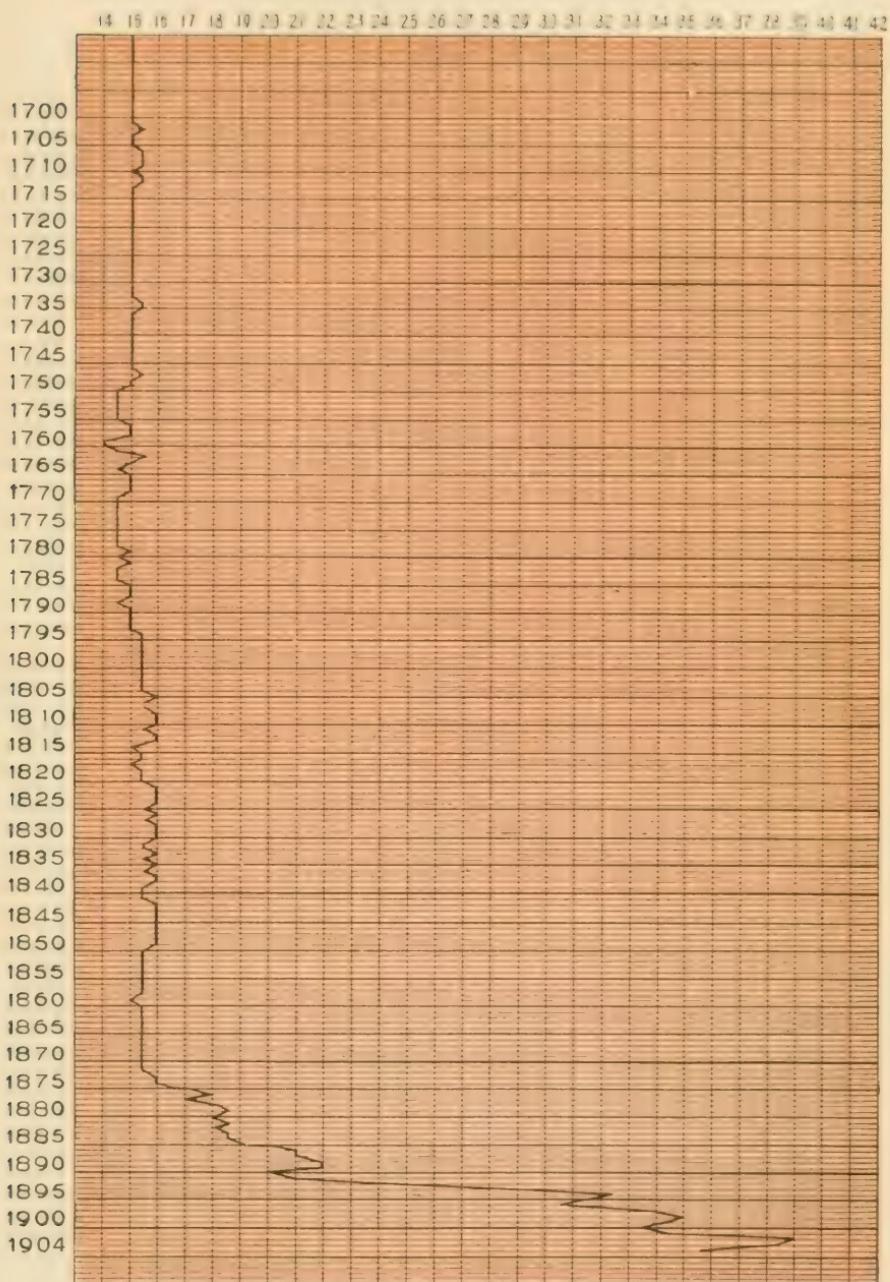
gain in the same interval has been $449,600,000, from which is to be deducted the falling off in several nations of $26,000,-000, and thus a net increase is shown of $423,600,000. At the present rate our gain will exceed that of all European countries. Remember also that their population is five times that of the United States. Let us concede that some excess crept into the estimates of earlier years in our stock, and has been carried forward; but the methods of calculation in France and Russia render it certain that like excess in greater degree exists in their records. The ratio is therefore practically accurate.

An interesting comparison is that by persons. Our stock of gold is $15.80 per capita; that of France is stated at $24.36; of Germany, $13.54; of Austria-Hungary, $6.01; of Russia $5.70; of Switzerland, $9.06; of Sweden, $3.42; of Norway, $3.73. With greater assurance and accuracy, we can consider and contrast the holdings of the treasury of the United States and of the foreign central banks. Let us take two dates five years apart and look at the totals and the changes in the interval, September, 1898 and 1903. The Bank of England in that period lost in gold, $2,264,000; the Imperial German Bank, $38,683,809, and Russia $132,240,-000, while gains are reported in the Bank of France, of $127,-640,000; of Austria-Hungary, $79,120,000. The aggregate gains in all the European states were $261,867,000, and the losses $181,571,000. Thus the net gains in official holdings in those states for five years were $80,000,000, and were equal to that of one year of our treasury.

The banks, national and other, own $322,000,000. Our treasury holds now $655,000,000. A fair comparison with foreign official holdings permits us to combine these sums, and to reach as the treasure on which our financial system is based $977,000,000, hard on to a billion dollars. The public and private credit of the British empire rests on $166,856,-000 in the Bank of England; of Germany on $170,371,000 in the Imperial German bank; of Russia on $404,396,000 in the Imperial bank; of France on $494,506,000 in the Bank of France. Exclude the gold of the banks; our treasury alone holds 3.9 times more than the Bank of England; 3.8 times

more than the Imperial German bank, nearly three times more than Austria-Hungary; 62.1 per cent more than Russia, and 32.6 per cent more than France.

This plethora of the precious metal in our country presents three problems interesting and important. What is to be the effect on our currency? What on prices and wages? What on our world relations? Paths may be opened for our investigation if we look back to the decade following the discovery of gold in California and study the conditions from 1850 to 1860. In that period our country produced gold of the coinage value of $550,000,000, an average of $55,-000,000 a year. With population ranging from 23,000,000 to 31,000,000, activity marked all branches of industry. In the census years the value of manufactures produced ran up from $1,019,106,616 to $1,885,861,676—an increase in ten years of $766,755,060. In the decade our national wealth increased by $9,023,836,000. Imports of merchandise grew from $173,509,526 to $353,616,119, more than double; from $7.48 per capita to $11.25; and exports from $144,375,726 to $333,576,057, again more than double, and from $6.23 to $10.61 per capita. The money in circulation increased from $330,256,605 to $435,407,252, and from $12.02 per capita to $13.85. Of this, bank notes were in 1850, $131,366,520 and in 1860, $207,102,477, and specie at the two periods, $154,-000,000 and $235,000,000. Prices of food and clothing advanced, and up to 1855 a general increase occurred of 11 per cent, but in the sum of articles chosen for index, there was a fall of 2.3 per cent before 1860. Pig iron, a typical product, went from $20.88 in 1850 to $22.75 in 1860. In Great Britain from the decade 1848-1857 to 1858-1867, there was an advance in index prices from 89 to 99.

The panic of 1857 befell in that decade. Howell Cobb, secretary of the treasury, pronounced "the undue expansion of credit, which engendered schemes of improvident speculation, leading to rapid fluctuations in prices and habits of extravagance, the principal cause for the embarrassments in the commerce of the country." Others vehemently attributed the disastrous revulsion to the change in the tariff made by the act of March 3, 1857, reducing rates by twenty

per cent. Looking back the student may ask, was not the shadow of the civil war a contributing cause? It is certain that all branches of business were prostrated and that the distress was wide and intense. The banks suspended, but the government kept on paying coin. While paralysis fell upon enterprise, the country was not exhausted as in the panic of 1837. Industry and commerce had been rushing on too fast, and the brakes worked suddenly with a severe shock. To-day the contrasts with that period are many more than the parallels. No sectional strife disturbs the national serenity. Our huge railroad system binds all states together, and connects ocean with ocean and the gulf with the great lakes. Our industries are more varied and so have a broader base. Enterprise takes more extensive range. They cannot be so easily toppled over. From 1890 to 1900 the annual product of our manufactures grew from $9,372,-437,283 to $13,039,279,566. Our imports of merchandise ran up from $789,310,409 to $849,941,184, and our exports from $857,828,684 to $1,394,483,082. We are 82,000,000, with so many electric brains and hearts beating to many rhythms and with chameleon desires. To such, general and sudden change does not come so readily as to a smaller population with simpler methods and with narrower experience. The magnitude and variety of our interests present increasing power of resistance to perils and to follies. The severest cyclone can not cover a continent, but has a short and narrow path.

Our currency rests absolutely solid on its rock bottom of gold. Some ghost seeing Macbeth may discern weird sisters on the blasted heath, casting their incantations together, with the refrain:

> "Double, double, toil and trouble,
> Fire burn and cauldron bubble."

He may dread the rush of United States notes for redemption, may suspect that some secretary of the treasury will use silver for official payments, may tremble at the hazard of wild legislation. He forgets that $260,000,000 of the United States notes are of denominations of $10 and below. How can they be gathered in any large volume? The silver dollars

are scattered everywhere, while the silver certificates are all but $27,000,000 in $10's and below. The people need all small notes and clamor for more. They are beyond reach by any secretary for large payments. The power of congress is vast, but it cannot climb Niagara, nor can it overcome the majestic force of this yellow flood of $80,000,000 a year.

Some critics complain that gold is not a cheap currency. That is true, and it is its merit; it is secure beyond doubt. Cheap currency may be devised, if that is wanted, but it will have all the qualities of cheapness; it will be weak, unstable, dubious. Gold is worth all it costs. It goes masterfully everywhere. It stands sure and steadfast itself, and all allied to it takes on its strength and power. Our yellow metal passes in St. Petersburg and Pekin, in Hongkong and Tokio, and the United States note and silver certificate march with it in equal favor. The American people were urged to make fiat money because it was cheap, and to coin silver at 16 to 1, because it was cheap. They rose above the temptation and declared not once but twice and always that they want not cheap money, but the best in the world. And they have it, and the annual inflow of $80,000,000 assures it to them and rewards their wisdom.

Possible peril lies on another side. Our circulation is undergoing an immense and continuous inflation. In five years, the money in circulation in this country has run up from $1,816,516,392 to $2,404,617,069, an increase of $588,-020,677. The strength is that of this growth, $358,604,872 has been in gold, coin and certificates, an annual addition in that form of nearly $72,000,000. We are to confront a further increase in our circulation, of which gold will constitute not far from $80,000,000 a year. That precious metal, including the certificates standing for it, is now 42.27 of the total, and its share advances steadily.

Since October 1, 1898 the circulation for each person in the United States has run up from $24.24 to $31.06 and the part of gold in it from $8.78 to $12.57. While nowhere else are checks and drafts and like instruments used to the same extent as with us, no other country has so much money per capita in circulation save France, which claims $39.22

where checks are much less used than here. Great Britain has $18.29, and Germany $20.48; Canada, $14.39; Russia has only $6.50. Differing from notes of national banks, gold is money of final reserve and redemption, and the credit built upon it is higher and broader, so that the potential inflation may be carried further.

In this country, cash is used for only ten per cent of transactions; in some localities for less; in others for perhaps fifteen per cent. Cries for more money have been often heard in the land; no one has said how much. The due limit for circulation has not been established. Alexander Hamilton quotes Postlethwaite as supposing that the quantity of cash necessary is one third of the rents to the proprietors, on one ninth of the product of the lands. This really only names other unfixed quantities as the standard. We have passed far beyond such limit. The theory has been proclaimed that the circulating medium should keep exact pace with the population. Conditions vary in different countries and at different periods. In the same land at periods not remote from each other, large additions to the currency can not fail to affect enterprise, industry, and commerce, the cost of living and the prices of commodities. But the currency is only one factor bearing on production and consumption. We shall err radically if we treat it as the absolute dictator.

With due allowance then for contrary influences, how far and in what direction is the vast inflow of the yellow metal carrying us? The blind may see that in the past five years business has been expanded in some directions in an unparalleled degree. Credit has naturally been multiplied at least to four times the amount of cash added to our supply. The exploitation of gigantic industrial corporations ran on at a dangerous speed, fortunately to exhaust itself by its own excesses. Promotion of stocks and bonds is not industry; it is speculation, and that finds help and impetus in inflation. In that way the inflow of gold has magnified if not wholly caused the frenzy and the excesses in industrial securities. Those who have climbed too high into the realm of credit must come down, and here the descent, unlike that to Avernus, is not smooth and pleasant. The promotor who has failed

to distribute his stocks and bonds may be punished, and those who have petted his schemes may suffer. A trust company which puts all its assets into one concern invites ruin. One swallow or two do not make summer. The failure of one bank or two does not create a panic. A shrinking of inflated securities to their true value is not a public calamity. Individuals may be crippled, industry and enterprise may have to rest on their oars. Our financial system cannot totter, much less be wrecked. Undue favors may have been shown by some banks to promotors, but they are correcting their blunders and looking out for more healthful business.

Prices of commodities have undoubtedly been borne upward by the inflation. Special influences have affected iron; Bessemer pig which was $10.25 in August, 1898, cost $21.75 at the same time in 1903; steel billets in the same interval have risen from $14.75 to $34; No. 2 red winter wheat which was 74 became $74\frac{1}{2}$; mess pork from $9.75 jumped to $18.25, and family beef from $11.50 to $15; cotton from $5\frac{11}{16}$ advanced to $8\frac{9}{16}$; Ohio fleece wool fell from 28 to 27.

By index numbers the advance of all commodities has been from $76.808 to $97.891, or twenty one points. On full examination, the Employers' association of Chicago finds that the cost of living in this country has increased fifteen per cent in five years. Carroll D. Wright, head of the bureau of labor, with all the data of the anthracite coal commission, declares the advance to be from fifteen to seventeen per cent. These figures may be accepted as authoritative. Advance in wages follows increase in cost of living. In recent years it has come fast and strong. Large railway companies and other corporations have added fifteen per cent at one step to wages paid, to meet the recognized advance in cost of living. The drift had been downward in wages from 1893 to 1898; since it has been steadily upward. In many cases it has exceeded the rise in cost of living. The general average may safely be stated at from fifteen to twenty per cent. Persons with fixed incomes are burdened with the heavier cost of living without any offset, as they have the benefit of a fall in prices of commodities, when that occurs. When wages go up, the purchasing power of those who earn them rises

in equal measure. This process affects prices of commodities, and adds always to the consumption which again gives impetus to production and trade.

No one can deny that the golden inflow contributes to the currency a share growing more rapidly than the total circulation, all at parity; that it lifts prices and wages, incites activity in industry and trade, and pushes enterprise forward, while it also tempts to undue inflation of commercial and stock jobbing credit. How do these influences bear upon our world relations? First of all, our surpassing wealth in gold has placed our national credit on a plane above that of all other countries, and never before held by that of any government. British consols bearing $2\frac{1}{2}$ per cent interest, long the foremost type of credit, have recently sold below 87, and German $3\frac{1}{2}$ per cent consols at 90, while consols of the United States bearing only 2 per cent, range from 108 to 110, and the loan of 1925 commands 136. This American republic alone among nations always in time of peace reduces its debt, and after a war makes rapid payment of the cost. Only unbridled folly, not conceivable, can shake this solid structure.

Obviously the supremacy of our national credit adds to the strength of the republic in commercial credit, general esteem and international influence in all the world. We fear no evil from exports of gold, for we can well spare more than Europe can pay for in American obligations, in merchandise or in any form of securities. The productiveness of our people justifies this rank. In manufactures the American people are far and away beyond rivalry. Against our thirteen billion dollars of annual product, Great Britain shows $4,263,-000,000, France $2,900,000,000, Germany, $3,357,000,000, and Austria-Hungary, $1,596,000,000. These four great nations turn out in manufactures, $12,116,000,000 a year, or a billion dollars less than does this country alone. The scale of living in the United States is such that we consume a great deal of what we make. We spend more than the same number of people anywhere else on earth. Our agriculture helps to feed Europe, indeed many of its inhabitants would starve without our grain and meats. How much of the products

of the farm shall be exported depends on the crops in all lands and on the purchasing power of our foreign customers. But we invade the old world with our manufactures by reason of the skill and energy of American labor and the methods devised by American genius. We run electric roads beside the pyramids; we furnish harvesters for Russia; we build bridges in the Soudan and in Burmah; send locomotives to farthest Manchuria, help Germany to load coal, sell shoes to Austria, scatter sewing machines everywhere, and our watches keep time on the Danube, the Nile and the Orinoco. Our high wages have not yet checked our invasion of the markets of Europe and Asia. Increasing home consumption affects to some degree the exports of our merchandise, for we ship only what our own people do not use, but the more we make the more we shall sell.

Upon the marvelous golden inflow, American mechanism moves in triumph. Our agriculture is still dominant in our wheat and meats and fruit and cotton. The remarkable growth is in our manufactures, now constituting nearly a third of our exports, and rock ribbed are our material and financial conditions. Predictions can prudently be based upon them. But the minds of men are a shoreless and chartless sea, and no one can tell when or why pallid fear may brood horribly upon its waves. The nerves of the multitude are a vast electric system which some accident may start into sparks or even flame and shock and far reaching utterances. Into this mystic region our theme does not lead us, even if we had the courage to enter there. We have been studying what can be weighed and measured, a stream whose course and force can be quite clearly mapped. This golden flood is without peer in its magnitude. It has brought to our people and our government treasures richer than any before recorded in human annals. It has covered the continent and blessed all the inhabitants. Its sources and its current are not exhausted. It continues to spread itself over every valley and plain, fructifying as the waters of the Nile. Bankers may do much to direct it into right and beneficent channels. They can prevent its diversion for sinister and harmful purposes. The strippings of the surface of the

mines have been brought to us. Riches from lower levels are within sight. If the American people are prudent, will let their common sense and cold reason govern, they shall see that the prosperity they enjoy is the earnest of more to come, of material achievement beyond the scope of prophecy, deserving to be adorned with moral and spiritual flower and fruit which shall glorify humanity.

WORLD'S SUPPLY OF COPPER.

BY JOSEPH M. SHEAHAN.

[Joseph Medill Sheahan, editor; born Chicago March 14, 1873; educated in the public schools and at St. Ignatius college; became connected with the Chicago Edison electrical company and later was a reporter and staff correspondent on the Chicago Tribune, during which he made a number of important investigations, including one of the mining situation in Pennsylvania; city editor of the Evening Post, 1905. Author of many articles for newspapers and magazines.]

In the story of copper lies a mystery that baffles the wise men of to-day. To trace back its history in America loses one in the dim past before history began. In all ages man has found it a most valuable metal, while to-day its uses are manifold.

The great copper deposits in the Lake Superior region were worked by races which have left practically no other record of their history. Copper is mentioned in the bible, although the term there employed is believed also to include brass and bronze. From the ruins of Troy have come articles wrought from pure copper, and Homer is authority for the statement that the combatants in the Trojan war were clad in bronze armor, bronze being a mixture of copper, zinc and tin.

The metal was much used by the Romans, who first learned of it from the deposits in Cyprus, where the Greeks had mined it long before, and from the Romans comes the modern name copper. They called it first aes cyprium, which in time was shortened to cyprium and then to cuprum, from which are derived the English, French and German names of the metal.

Among the Romans copper was considered the metal especially sacred to Venus, and alchemists in their writings designated it by the cymbal, known as the looking glass of the goddess.

The early chemists believed that when iron precipitates metallic copper from solutions of its salts a transmutation of iron into copper takes place. It was not until the seventeenth

century that chemists recognized the elementary character
of copper.

Copper is found either native or combined with cuprite
(the red oxide); tenorite, (the black oxide); chalcocite (sul-
phide); malachite (green copper carbonate); chalcopyrite
(copper and iron sulphide), and bornite (black copper and
iron sulphide). It is found also in many other minerals,
atacamite, bournonite, and enargite among them. Sea water
contains copper, as does seaweed. The metal is found also in
the blood of animals, in eggs, in flowers and in plants.

Copper is widely distributed over the world, but the
countries that are the chief sources of supply are the United
States, Spain, Germany, Japan, Australia, Mexico and Chili.
The following table shows the growth of the world's produc-
tion of copper since 1800:

[Long tons.]

DECADE.	World's production of each decade.	Increase of production over previous decades.	Average annual production for each decade.	Increase of average annual production
1801 to 1810	91,000	....	9,100	....
1811 to 1820	96,000	5,000	9,600	500
1821 to 1830	135,000	39,000	13,500	3,900
1831 to 1840	218,400	83,400	21,840	8,340
1841 to 1850	291,000	72,600	29,100	7,260
1851 to 1860	506,999	215,999	50,699	21,599
1861 to 1870	900,000	393,001	90,000	39,300
1871 to 1880	1,189,000	289,000	118,900	28,900
1881 to 1890	2,373,398	1,084,398	237,339	108,439
1891 to 1900	3,708,901	1,335,503	370,890	133,550

Up to the period from 1895 to 1898 the United States
was rapidly gaining over all other countries. From 1887
to 1894 practically all the increase in the world's production
of copper came from the United States. During the years
from 1895 to 1898 the United States outranked all other
countries. During the last period, closed by the census year
1902, the production of the United States maintained its
rate of growth, but mining in other countries took on a new
life under the stimulus of high prices, and the increase in
their output nearly reached that of the United States.

Among all the copper producing countries the United
States is supreme, for within its boundaries is produced
nearly two thirds of the world's supply. Next comes Spain
with an output of about ten per cent of the total output.

Among European producers the Iberian peninsula holds the first place. Prior to 1882 its output exceeded the production of the United States, and, in 1882, both countries were on the same level, but within the following twenty years the production of Spain and Portugal increased by only about 25 per cent, while the production of the United States is now more than seven times as large as it was twenty years ago.

Mexico, which prior to 1894 was but a small factor in the world's production of copper, has since that year more than trebled its output and gained third place among the copper producing countries.

Next after Mexico was Japan, which since 1890 has doubled its output, and Australia, whose progress has been still more rapid. Germany has shown no appreciable gains since 1896, and has been outranked by Mexico and Australia.

In the United States copper has been mined since the early part of the eighteenth century and shipments of the ore were made as early as 1731. The first deposits to be worked were in Connecticut, New Jersey and Pennsylvania. As an important industry, however, the history of copper dates from 1844, when the Lake Superior region was opened. At that time the country's output was small, but it grew steadily and rapidly. In 1880, 27,000 tons were produced. Then with the extension of railways through the west the rich deposits in Montana and Arizona were opened to the markets of the world and the United States rapidly left its rivals behind.

In fact, the development of the western copper deposits has given this country its present pre-eminent place among the copper producing nations.

The copper mines in the upper peninsula of Michigan (the Lake Superior region) are unique. The ore is native copper with some silver, but containing hardly any other impurities. It is found as a cement binding together or replacing the pebbles of a conglomerate, as a filling in an amygdaloidal diabase, and as irregular masses in veins. These veins have yielded immense masses of copper, but because of their formation they cannot be worked at a profit when copper prices are low.

WORLDS PRODUCTION OF COPPER
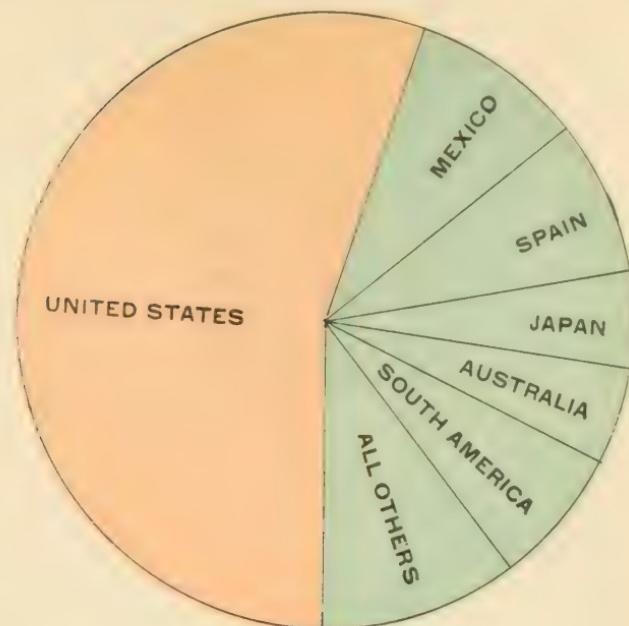
WORLD'S PRODUCTION OF LEAD
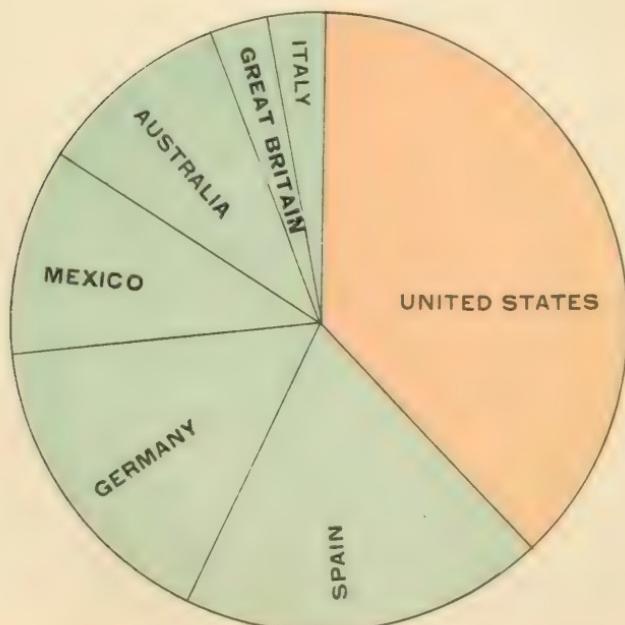
At the present time the productive mines are located in the conglomerate or in the diabase, the ore averaging from six tenths to four per cent copper. The Calumet and Hecla is the richest and largest of all the mines in this region. This district has been an active producer for over fifty years and still promises many years of productiveness because of its favorable conditions for deep mining.

The greatest development of the copper mining industry in the United States came, however, with the opening of the deposits in Arizona and Montana. The latter state now produces about 43 per cent of the country's supply, Arizona about 22, and the Lake Superior region 29. The following table shows the share contributed by each state or territory to make up the country's total:

	Pounds.	Value.
Arizona	121,409,275	13,367,135
California	26,549,063	3,055,908
Colorado	5,841,074	450,355
Georgia	9,500	1,235
Idaho	86,442	9,149
Michigan	171,102,065	20,100,425
Montana	268,440,090	30,092,781
Nevada	29,114	3,134
New Mexico	8,017,902	462,053
North Carolina	418,801	45,531
Oregon	46,154	2,800
South Dakota	787	67
Tennessee	12,284,515	1,316,991
Utah	24,720,824	2,272,692
Virginia	3,246	398
Washington	72,540	10,890
Wisconsin	....	210
Wyoming	2,000	260
Total	639,033,392	$71,192,014

Montana's most productive mines are found near Butte. The deposits occur as fissure veins in granite and consist of bornite, chalcopyrite, chalcocite, and other sulphides. Immense quantities of ore averaging as high as 40 per cent copper have been found, but as the mines have been sunk deeper there has been a gradual decrease in values. At present the average is probably about 5 per cent. For several years the Anaconda maintained a yearly output of over 100,000,000 pounds.

Next in importance as a producing region comes Arizona, with its deposits at Bisbee, Clifton and Globe. The Arizona ores are carbonates, oxides and native copper. They are found only in carboniferous limestone and porphyry. The

ore is rich and easily smelted, but the companies mining it are handicapped by scarcity of water, cheap fuel and inadequate transportation facilities.

Copper is found also in California, Colorado, Utah, New Mexico, Tennessee, and Vermont, but these deposits are of relatively little value. There is also one mine in Wisconsin.

The exporting of copper from this country showed its first decided gain over the domestic supply in 1896, whereas in all other copper producing countries the supply available for export exceeded the direct exports to Europe. The excess of the exports from the United States in 1901 and 1902 was very near the surplus of all other countries, after deducting their direct exports to Europe. These figures demonstrate that the United States has within late years gained control of the export trade of non-European copper producing countries.

A study of statistics reveals that the direct exports of copper to Europe from Canada and Mexico have fallen off slightly, while the supply of copper available in these countries for export has more than trebled since 1895. All this copper found its way to the United States, to be re-exported to Europe. The direct exports to Europe from Canada and Mexico are but a minor portion of their total copper exports. The United States has also a fair share of the copper trade of Japan, Australia, and Chili, though these countries for the most part maintain direct relations with Europe.

Germany is the largest consumer of American copper, depending upon the United States for more than half its supply. Great Britain ranks second among the consumers, with France third, the latter country having developed a large demand for American copper since 1896. At present two thirds of that country's supply is derived from America.

Copper is a red colored metal with a bright metallic luster. The specific gravity of finely divided copper is 8.36, while that of hammered copper is 8.95. The metal is exceedingly malleable and may be rolled into thin leaf or drawn into a fine wire. Its melting point is 1100° C., and it burns with a green flame. The enormous increase in the

PRODUCTION CONSUMPTION AND EXPORTS OF COPPER IN THE UNITED STATES 1895 TO 1902.

AVAILABLE FOR EXPORT — — — — CONSUMPTION
.... PRODUCT OF MINES
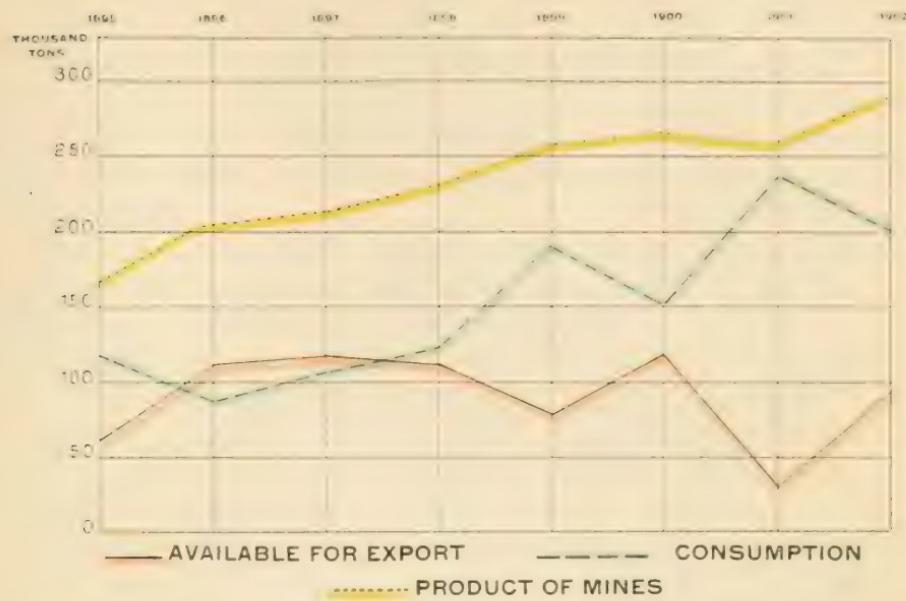
EUROPEAN DEMAND FOR IMPORTED COPPER

——— NET DEMAND FOR IMPORTED COPPER
.... SUPPLIED BY UNITED STATES
— — —SUPPLIED BY OTHER COUNTRIES
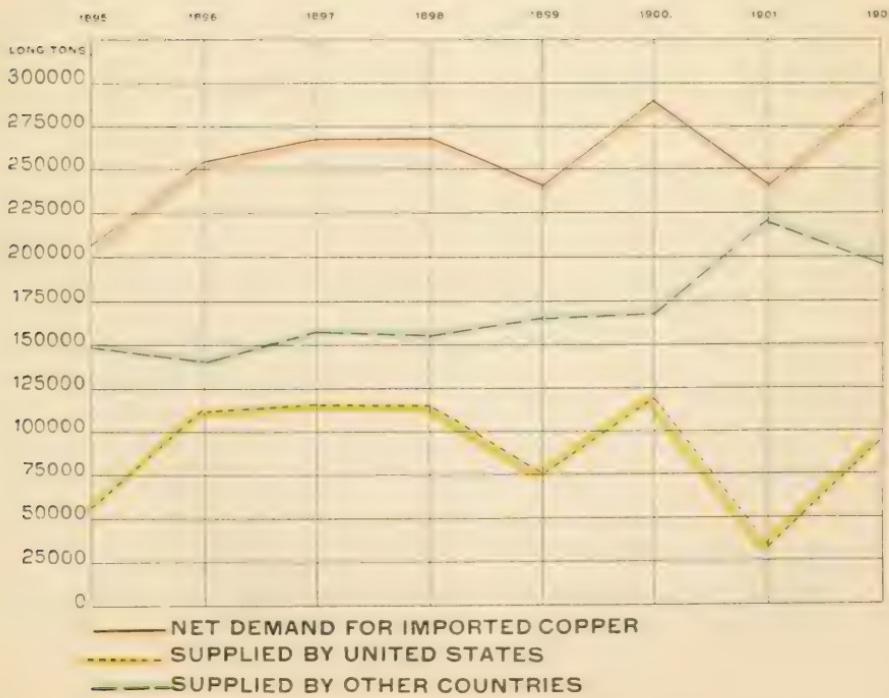
use of copper in recent years is due to the fact that it is, next to silver, the best conductor of electricity.

But copper has many other uses. It is employed in the manufacture of tubular boilers, for the sheathing of ships, for electrotypes, in coinage and in many other ways too numerous to mention. It is valuable also for use in the form of alloys with other metals, its principal alloys being brass, bronze, bell metal, speculum metal, aluminum bronze and German silver.

In combination with oxygen, copper forms four oxides, quadroxide or sub-oxide; cuprus oxide, hemioxide or protoxide; cupric oxide or monoxide; and peroxide. Cuprus and cupric oxide are the most important of the four. Cuprus oxide, which is found native as cuprite or red copper ore, is used in the production of ruby glass. Cupric oxide is found native as tenorite or black copper ore, and is used in making green and blue glass and as a pigment.

Of the copper salts the most important is cupric sulphate or blue vitriol. It may be prepared by dissolving metallic copper or its oxides in sulphuric acid. It is used extensively in calico printing, in dyeing, in the preparation of pigments and for the preservation of timber and in agriculture. Many other compounds are extensively used in pigments.

In the extraction of crude copper from its ore three methods are employed. They are known as the wet, dry, and electro-metallurgical methods. Where the wet method is employed the copper produced is called black or blistered copper. It contains a number of foreign substances which must be removed before it can be used. It is refined either by the dry or electrolytic methods. The most important ores of copper are the sulphuretted compounds. Next in order come the oxides, carbonates and silicates of copper, as well as native copper, containing impurities. All these ores when sufficiently rich are treated by smelting or by the dry method. Only when ores are so poor in copper that no other method can be used profitably is the wet process used.

The dry methods of copper smelting are several. They include blast furnace smelting, known also as the German

or Swedish process; reverberatory or English smelting; and the converter or Bessemer process.

The blast furnace process consists in roasting the ores in special appliances, following this by smelting the roasted product with coke or charcoal in blast furnaces. The series of chemical reactions which result during this treatment are too technical to set forth here, but the result is copper matte, a mixture of copper, sub-sulphide and some of the original impurities of the ore.

This matte is then commonly enriched by partly calcining it and again smelting it in the blast furnace, although this second process is not always employed.

The matte then is roasted and then smelted with siliceous fluxes in addition to the carbon which is used in the first smelting to produce coarse or black copper.

In the reverberatory process the ore is first partly calcined and then is smelted in a reverberatory furnace with a quartz lining, with the addition of siliceous materials or ores if necessary. The resulting matte then is concentrated by being partly roasted and then smelted again in reverberatory furnaces.

The matte resulting from the concentrating process is converted into crude copper by partial roasting followed by fusion in reverberatory furnaces. The converting process is not applied to ores, but is usually employed to reduce to coarse copper the matte produced by either the blast furnace or the reverberatory method. This converting process consists in blowing a highly subdivided stream of air under pressure, through molten matte which is contained in a pear shaped or cylindrical converter lined with quartz ore material. The matte to be blown is first melted in cupolas and then run into the converters.

Wet methods of reduction consist in getting into aqueous solution, by means of suitable solvents, the copper which of necessity must occur in some combination suitable for solution, and of precipitating it from these solutions by suitable precipitants. The precipitate thus secured is refined by the dry process. The copper ores to which this wet process is applied contain the copper in the form of oxide, car-

bonate, sulphate and sulphide. The cheap solvents usually employed are water, hydrochloric acid, sulphuric acid, or solutions of metallic chlorides.

The electro-metallurgical method of extracting copper is used principally in extracting copper from alloys of the same metal and the precious metals. Briefly the process is as follows:

The ingot of alloy is attached to a conductor from one pole of a dynamo and a sheet of copper is attached to the other pole and both are immersed in an acid solution of sulphate of copper. A current of electricity then is passed through the solution between the poles and dissolves from the ingot the copper and deposits it on the copper plate, the other metal falling to the bottom of the tank. This method is properly a refining process applied to alloys, rather than an extracting method, but it has been applied to the extraction of copper from the ore and matte, although such use is not extensive at the present time. This same process can be used in refining coarse copper, but not with profit unless the copper is alloyed with gold, silver or nickel. The method usually employed in refining coarse copper is to fuse it in a reverberatory furnace, subjecting it to the oxidizing influence of the air, and then to reduce the cuprus oxide formed by stirring the molten mass with a green wood pole.

COPPER ORE IN DIFFERENT PARTS OF
THE COUNTRY.

BY ARTHUR LAKES.

[Arthur Lakes, geologist; late professor of geology at the Colorado state school of mines; he has made exhaustive studies of gold and silver ores and is one of the leading authorities on western ore deposits; he has written much for the technical and scientific press, and is the author of Prospecting for Gold and Silver in North America, Geology of the Colorado Coal Fields, Geology of Western Ore Deposits, etc.]

In the granites and schists of the Atlantic coast, although the range is generally mineralized and copper is distributed here and there, only in a few places is it sufficiently concentrated to be of working value. In the northern region the original unoxidized copper pyrites reach almost to the grass roots and there is but little oxidized ore. But from Virginia to Tennessee, where oxidation is great, decomposition, accompanied by a natural smelting and concentration of copper ores, extends to considerable depths. Here we find a zone of barren iron oxide derived from pyrite, the leaching of which furnished the copper to enrich the lower zone. The vein resumes its true unaltered character as yellow copper pyrites carrying a very small amount of copper, viz. 3 to 5 per cent, out of all proportion to the great expectations derived from the rich copper concentrations in the oxidized zones near the surface.

In the Lake Superior region the ore occurs in beds in trap and conglomerate. In Michigan the copper is in a native state, probably derived from solution from oxidation of copper sulphides in the underlying Huronian rocks.

In the Keweenaw peninsula there are three classes of deposits: (1) Well defined veins. (2) Copper in amygdaloidal dikes. (3) Beds of conglomerate, the pebbles cemented together with copper.

In considering the mode of occurrence of copper, the main point to be kept in view is the change in character and value of the ores as depth is attained, and as the oxidized surface ores pass down into their unoxidized, normal, and original condition.

The unreliability, as a rule, of the gay colored and richly assaying surface oxidized ores, compared with the character of the ore they pass into at depth, is very striking and important, and the prospector, miner, and purchaser cannot be too guarded in this respect.

So little reliance is to be placed on these surface ores and their continuity downward to any great depth, that, often, not until the zone of unoxidized pyrites is gained, can the future value of the mine be predicted, and the test of the values of this unoxidized zone is often sadly disappointing and at great variance with the expectations derived from tests on the rich surface ores.

The principal American regions are the Atlantic coast, Lake Superior, the Rockies, and Sierra Nevada. In most of these, granitic and eruptive rocks predominate. In the southwestern region, Paleozoic limestones of the Carboniferous series are the prevailing carriers of copper ores, but only where these are closely associated with eruptive rocks, which may themselves contain copper, and doubtless were the means of impregnating the limestone with it by metasomatic substitution, like the lead silver ores of Leadville, Colorado, which are also at the contact of porphyries and limestones.

The beds of volcanic ash and amygdaloid (i.e., cavities formed by escape of steam in a surface lava flow and filled with copper instead of, as commonly, by calcite, or zeolitic minerals) are very profitable. So are the beds of conglomerate, which have produced many millions of pounds of copper.

In the Rocky mountain and Sierra regions we appear to have a variety of copper bearing rocks of different kinds and different ages. We have granites and pre-cambrian crystalline schists and gneisses, characteristic of the mines of Butte, Montana, and the United Verde of Prescott, Arizona.

Paleozoic limestones and sandstones associated with eruptive rocks as at Bisbee, Clifton, and Globe, Arizona, and Tintic in Utah, and what we may call the southwest region. Mesozoic sandstones and shales metamorphosed by contact with great eruptive bodies of diabase and other volcanic rock, as the pyritous beds of California.

In portions of Texas, Colorado, and New Mexico, the

red Jura-Trias beds of sandstone are often stained with copper, but rarely yield copper in workable quantities. In Butte, Montana, from which many millions of pounds of copper have been extracted, the ore comes from a small granitic area, a mile wide, by two miles long on the western slope of the Rockies. The distribution of the ore is irregular, extensive bodies being found on breaking through an apparently well defined wall. There is often no defined line between vein and country rock. The ore occurs in chutes extending for several hundred feet along the strike before pinching out. The depth of these chutes is often greater than their length. The veins may be from a few inches to 100 feet in thickness of ore, 5 feet to 6 feet being the average.

The outcrop of the vein appears as a brownish iron stained quartz passing down with depth into red and yellow oxides carrying gold and silver. These decomposed ores extend down towards water level 40 to 300 feet, and then begins the rich zone of secondary copper ores. The copper minerals of this zone pass through all the gradations from pure rich copper glance to copper pyrites and iron pyrites; bornite, or purple copper, appears as a conspicuous element.

These secondary ores diminish in value with depth and again this diminution lessens with greater depth; the ore is said to average 6 per cent copper and five ounces silver to the ton of 2,000 pounds. The Butte mines, however, make more profit from their 6 per cent ore than formerly from ore double that richness, owing to improvements in treating ore. At a depth of 1,300 feet there is no sign of waning.

The earliest knowledge of copper in the southwest was from Mexicans who, in the latter part of the last century, discovered the Santa Rita mines in New Mexico, near the present town of Silver City. The Mexicans called these mines Creadera del Cobre, the place where copper was created, the native metal cropping out on the ground. Masses a ton in weight were extracted and shipped to the City of Mexico to be coined into copper money. In 1838 the Apaches drove out the miners, and not until 1873 were the mines resumed under American management. In 1865 Colonel Carleton's California volunteers pursuing Indians discovered Copper mountain,

or the present Clifton mining district in Arizona, and work was begun in 1894. The building of the Southern Pacific and Atlantic Pacific through southern Arizona developed the mines and exerted a marked influence on the copper industry. The principal districts are the Warren, Globe, and Black range.

From an interesting description by Mr. A. F. Wendt, we note that copper in that southwest region may occur, as at the Santa Rita mines, New Mexico, at the contact of limestone, and an eruptive rock, such as felsite porphyry, i.e., a rock composed of a paste of feldspar in which are set distinct crystals of feldspar like plums in a pudding. The original openings by the Mexicans show that they found native copper in the felsite disseminated through it in shots, flakes, leaves, and even in broad, thin masses, 2 feet square. Sometimes this copper is altered into a red cuprite, an ore not unlike cinnabar in color, sometimes in fine hairs, resembling red plush velvet. A smelter erected did not find these ores in the felsite very profitable, but at the contact of the felsite and limestone, green carbonates and oxides of copper occurred, which were profitably mined and smelted.

At the junction of the limestone and the felsite, an enormous outcrop of brown hematite or iron oxide occurs. This may be the gossan, cap, or blossom of underlying copper ore. Such brown, rusty gossan is an almost invariable surface outcrop of a copper vein.

In the Clifton district of Arizona, one of the oldest and largest producers in the southwest, we have a basin surrounded by an almost circular range of mountains. A significant sign to the prospector of the character of the ore contained in this basin is that the water of Chase creek, issuing from it, is so highly charged with solutions of copper that it is undrinkable. The copper in this solution is doubtless in the condition of a sulphite popularly known as blue vitriol, and as its composition is sulphuric acid, copper oxide, and water, its unpalatable character can readily be imagined and accounted for. There are springs issuing from a copper lead in Bingham canyon, Utah, so strongly impregnated, that by throwing scrap iron into them a considerable amount

of metallic copper is precipitated and collected. The center of this Clifton basin is a vast mass of porphyry, surrounded by carboniferous limestones and sandstone, the latter abutting against an eruptive body of granite. Copper in this southern region seems intimately connected with volcanic rocks, both ancient and recent.

The ores of the Clifton mines occur in limestone, porphyry, and granite. In the limestone they occur as oxides and carbonates, such as hematite, cuprite, green malachite, or blue azurite mingled with black manganese.

In the porphyry and granite the ores are oxides near the surface, changing with depth into dark gray copper glance, and deeper still into the original ore, viz., yellow copper pyrites.

The Longfellow is the principal mine. The first discoveries were in pockets cropping out on the crest of Longfellow's hill in decomposed limestone altered largely into clay. On approaching the underlying sandstone native copper appears and the veins pinch and become barren.

On the rise of the vein above the Longfellow adit, large chambers of ore have been found in a manganese ore, yielding 38 per cent copper; 1,000 tons yielded 17.17 per cent copper. The vein is in a vertical fissure in limestone at contact with a dike of felsite. The ore replaces the lime, as at Leadville, Colorado, and occurs in irregular bodies. The ore is found in conjunction with large bodies of clay from decomposed rock resulting from the action of fumaroles, or hot springs, steam and hot solutions, during the deposition of the copper ores.

Another class of ores are in a stockwork of quartz veins in the porphyry and deteriorate with depth. These ores, though attractive on the surface have, like many other metallic mines, grown poorer with depth. The decomposed oxidized surface ores are the richest and the undecomposed ores underlying the surface are poorer in copper and more difficult to mine. This is commonly the experience with a large majority of copper mines, such as the copper pyrite mines of the Alleghanies and some of the Lake Superior mines, where rich

black oxides and accumulations of native copper are of frequent occurrence when opening the mines.

The Coronado mines (Arizona) are an example of a rapid depreciation of copper ores with depth. Surface ores assayed 6 to 45 per cent copper, and bodies of pure copper glance cropping out at the surface seemed to indicate a large future value underground. A tunnel 150 feet long was in solid copper glance 1 to 2 feet wide, averaging 40 per cent metallic copper. The vein is 5 to 15 feet wide, traceable through the porphyry dike. The walls are decomposed and kaolinized. Where the vein is not decomposed it is poor.

Copper glance in the Coronado mines occurs massive, but disappears at a depth of 150 feet, being replaced by yellow copper pyrites, sparingly disseminated. Analysis shows from 11 to 21 per cent copper. In the granite the ore occurs also as copper glance, but not continuously. The ores of the Bisbee district, Arizona, are also in limestone at contact with porphyry.

Copper signs can be traced in the district for five miles with occasional large iron caps or bodies of iron oxide which may mark copper bodies below. In the southwest region it is observed that when the outcrop is compact and not porous, honeycombed, spongy, or decomposed, no copper is found beneath. In the Silver Bear claim, oxidized copper ore changed into copper glance and soon played out.

The ore in the Globe mine is in a great continuous chimney running 23 per cent copper. At the Black range the ore is at contact of diorite and slate in a tableland of limestone; below the surface zone of carbonates and oxides is one of sulphurets carrying silver as well as copper.

It has been noticed that in some mines rich deposits of native silver are found, just at the line of demarcation between oxidized and unoxidized ores. In the southwest the successful mines are in a carboniferous limestone at contact with eruptive diorites, felsites and porphyries.

As long as the veins remain in the limestone they are profitable, but on entering the eruptive, or acid rocks, be it sandstone or porphyry, the veins narrow. The more and thicker the limestone is the better and thicker the ore.

BAUXITE.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York city in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

The mineral bauxite was first discovered in the year 1821 near Baux, France, by the well known French chemist, Berthier. He attempted to utilize it in the manufacture of alum, but, because of the large proportion of iron oxide it contained, he was unsuccessful. Later a deposit of the white variety, of greater purity than that of Baux, was discovered at Herault, also in France. The mineral did not, however, become of commercial importance until 1868 or 1869, when Sainte-Claire Deville, a French scientist, in the course of his experiments in the manufacture of aluminum, discovered the value of bauxite as an ore of this metal.

In 1881 occurred the first recorded discovery of bauxite in the United States. The find was made by Edward Nichols, at Hermitage, Floyd county, Ga. Afterwards deposits were found in Polk, Bartow, Gordon, and Chattooga counties. In 1891 R. S. Perry reported the discovery of the mineral in Calhoun county, Ala., although it had previously been found in that state in Cherokee county, where it had been known as iron ore blossom and as Clinton fossiliferous iron ore. Other deposits were afterwards found in Cleburne county. In 1891, too, the mineral was reported by the Arkansas geological survey as having been found in Saline and Pulaski counties of that state. Other deposits have been found, notably in North Carolina, South Carolina, and New

Mexico, but they are too limited in extent, and are too far from transportation facilities, or else contain too many impurities to be of value commercially. Arranged in the order of their outputs, Georgia, Alabama, and Arkansas furnish the total production of the United States.

The mining of the ore in this country is of comparatively recent inception, and, quite naturally, it has not reached a high state of efficiency. The mines are irregular holes dug in the hillsides, with deep, open drainage ditches leading from them. Below the surface the ore is sufficiently soft to be removed with pick and gad, which renders the extraction easy and lessens the cost of production. For a high grade product, however, the uneven quality of the ore makes necessary a sorting by hand or by screens. Screen sorting is generally preferred to hand sorting when the character of the ore will admit of the use of the screen. During the sorting process, when clay is mixed with the bauxite, a common log washer is occasionally used to separate it. The sorted product is then dried in the air or in kilns or furnaces prior to its shipment to market. In this process very satisfactory results have recently been secured from the use of furnaces of the revolving cylindrical type.

Refining was formerly done almost exclusively in Pennsylvania and New York, but recently new refining plants have been erected at Bauxite, in Saline county, Ark., and near East St. Louis, in St. Clair county, Ill. These plants are equipped with modern machinery, and hand labor has been superceded wherever practicable.

France produces three varities of bauxite: The white of Herault; the pale of Baux and other localities of southern France; and the red, which contains a large proportion of iron oxide, and which is also found in several places in southern France. Of these, the white variety is the purest, containing from 65 to 74 per cent of alumina, from 0.25 to 3 per cent of ferric oxide, and from 12 to 18 per cent of silica. Thus it is comparatively free from iron oxide but contains a relatively large amount of silica. The most impure is the red variety, which contains from 50 to 62 per cent of alumina, from 24 to 28 per cent of ferric oxide, which imparts the red color, and

from 1 to 7 per cent of silica. French bauxite is used chiefly in the manufacture of alum and alumina—the white variety, containing but little iron oxide, for alum; and the red variety, containing but little silica, after purification, for alumina. Because of the low cost of mining and the low ocean freights of recent years, large quantities of this mineral have been brought to the United States and consumed, mainly for the manufacture of alumina from which metallic aluminum has been made. At the present time there is little, if any, French bauxite used for the manufacture of aluminum sulphate.

In the United Kingdom there are important deposits at Strain, near Ballyclare, and at Glenravel, both in county Antrim, Ireland. Of the European deposits, these are next in importance to those of France. An extensive use of this mineral of county Antrim for the manufacture of aluminum has been retarded, because the high percentage of silica it contains renders it inferior for this purpose to the bauxite of France. It is, however, of excellent quality, and contains but little iron oxide or titanic oxide. Much of the product of the Irish mines is consumed in England, where it is made into alum.

In Germany there are several deposits of bauxite of considerable extent, but the quality is inferior to that of the French mineral. In one locality, however, the mineral is quite pure, but the deposit is too small in extent to be commercially valuable.

Austria, Italy, Asia Minor, French Guiana, and New South Wales also possess deposits of the mineral, but as yet none has been developed to the productive stage.

The mineral bauxite is a hydrated aluminum oxide containing also various quantities of ironoxide (Fe_2O_3) and silica (SiO_2). Three varieties are distinguished, the monohydrate (Al_2O_3,H_2O), the dihydrate ($Al_2O_3,2H_2O$), and the trihydrate ($Al_2O_3,3H_2O$). Apart from impurities the composition of these minerals varies from the monohydrate (diaspore), which contains 85.12 per cent of Al_2O_3 and 14.88 per cent of H_2O, to the trihydrate (gibbsite), which contains 65.61 per cent of Al_2O_3 and 34.39 per cent of H_2O. More or less of the alumina in bauxite is replaced by iron or manganese oxides. Silica

occurs in the mineral either free or in combination in clay. Minor impurities are compounds of phosphoric acid, sulphur, carbon dioxide, lime, and magnesia. In composition the French mineral appears to correspond to the monohydrate while that of the United States approximates the trihydrate. The composition of bauxite can be determined only by chemical analysis since it is not indicated by the physical properties of the mineral. According to Francis Laur, the average composition is from 66 to 69 per cent of Al_2O_3; 27 per cent of H_2O, SiO_2, and F_2O_3; with from three to four per cent of TiO_2 and other impurities. In general the value of the ore is in direct proportion to the richness and purity of the alumina content. In ore of good quality the percentage of alumina is high, while that of iron oxide and silica is low. Bauxite has a strong affinity for water, which makes it necessary that the ore be dried before shipment. For the manufacture of aluminum the presence of iron oxide and titanic oxide in the ore is not objectionable, but for making alum these insoluble materials should not exceed 7 per cent, and the iron oxide should be less than 2.75 per cent. The trihydrate, on account of its greater solubility, is best suited for the manufacture of alum, and for this purpose the bauxite of the United States is preferable to that of France.

Bauxite occurs in the earth's crust in the form of veins, beds, or amorphous masses, not crystallized, and without any constant organoleptic characteristics. The hardness, color, texture, and density often change in the same deposit. Usually the ore occurs in concretionary or pisolitic masses, although it is sometimes a hard, compact, homogeneous fine-grained rock. In some cases the structure is oolitic, and in others it is earthy, resembling clay. It may be hard or soft and compact or porous. The color varies from pure white to a deep red or black, passing through shades of cream, gray, yellow, and pink. The mineral is sometimes speckled or mottled, and is more or less stained by iron oxide, manganese minerals, or organic matter. The colors shade into one another gradually or abruptly, and seldom, if ever, does a deposit possess a uniform color. The hardness of average

good ore varies from 1 to 3 and the specific gravity from 2.4 to 2.55.

When exposed to extreme heat bauxite becomes so hard that it is almost impossible to make any impression upon it with steel tools. This property in connection with its infusibility makes it an excellent material for crucibles and for furnace linings, since it resists chemical and calorific actions. The chief reason why bauxite is not used more extensively as a basic furnace lining is due to the impurities that are usually present in the mineral.

Four principal substances are prepared from bauxite, viz., aluminum sulphate, alum, artificial emery, and aluminum hydroxide. From the last named substance the metal aluminum is manufactured.

Aluminum sulphate $(Al_2(SO_4)_3,18H_2O)$ is a chemical salt technically known as concentrated alum. It is prepared by decomposing bauxite with sulphuric acid. If the mineral is dissolved directly in the acid, the product will contain a large quantity of iron, forming the so-called alumino-ferric cake, which is used for many purposes where iron and free acid are not objectionable, as in the precipitation of sewage and of waste liquors from dyeworks. Pure aluminum sulphate is now generally prepared by the Bayer process, which consists in adding powdered alumina to the solution of sodium aluminate, containing one part of Al_2O_3 to 1.8 parts of Na_2O. The reaction causes a crystalline precipitate of aluminum hydroxide. The silica and the iron present remain dissolved in the solution. The precipitated aluminum hydroxide is separated from the solution and is thoroughly washed and later dissolved in pure, hot, concentrated sulphuric acid until the frothing ceases. The solution is then transferred to shallow leaden pans and allowed to cool; thus the pure aluminum sulphate is separated out in the form of a solid crystalline mass. Owing to its greater purity and greater strength, aluminum sulphate has largely replaced alum in the arts. Aluminum sulphate is extensively used as a mordant in dyeing; in preparing size for paper; for making alum and aluminum salts (red liquor, etc.); in tawing skins; for

precipitating sewage or coloring matter in water; and, in general, for all purposes in which alum was formerly used.

Potassium alum($K_2SO_4,Al_2(SO_4)_3,24H_2O$), is known also as potash alum and common alum. The manufacture of alum from bauxite involves the preparation of a pure solution of aluminum sulphate to which is added the proper proportion of an alkali sulphate in order to form the special alum desired. Thus potassium sulphate is used to form potassium alum and sodium sulphate for sodium alum. All alums crystallize from solutions perfectly, forming very pure crystals even from impure solutions, and it is because of this property that the alums are so extensively used in the arts. The chief uses of common alum are as a mordant in dyeing; in preparing size in paper making; in tawing skins; in making pigment lakes; for clarifying turbid liquors; for precipitating sewage waters; and for hardening plaster of Paris casts and other forms. For these uses, however, as mentioned above, aluminum sulphate is generally preferred because of its greater strength and solubility.

The manufacture of aluminum hydroxide from bauxite is of great importance, because by a simple calcination it yields aluminum oxide (alumina), which is the chief crude material used for the manufacture of the metal aluminum. In making aluminum hydroxide, bauxite is roasted, pulverized, and mixed with calcined soda ash in the proportion of 1 part of Al_2O_3 to 1.1 parts of Na_2O, or greater if silica be present in the ore. The mixture is calcined at a white heat for three or four hours until all traces of carbon dioxide and water have been expelled. The calcined product is then ground and lixiviated with hot water; this process yields a solution of sodium aluminate from which the aluminum hydroxide is precipitated by passing carbon dioxide gas through it. The impurities, silica and iron oxide, remain dissolved in the mother liquor.

In order to avoid the costly and tedious chemical process of obtaining pure aluminum hydroxide, an electric furnace method has been recently patented by Mr. Charles M. Hall, whereby the impurities in the bauxite, mainly iron oxide and silica are removed, and the bauxite is thus purified for the

aluminum reduction process. The process of purifying the bauxite consists in submitting it to a preliminary heating for some hours in the presence of carbon and metallic aluminum in an electric furnace, during which time the iron oxide and the silica become reduced to metallic iron and silicon and combine with the aluminum to form a heavy alloy, which can be detached easily from the mass of purified bauxite after it has cooled.

Within the past year or so a company at Niagara Falls, N. Y., has consumed a considerable quantity of bauxite for the manufacture of abrasive wheels.

LEAD AND ZINC ORE.

BY ISAAC A. HOURWICH.

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The earliest discovery of lead on the American continent is recorded fourteen years after the landing of the first English settlers in Virginia. In 1621 lead deposits were found in the vicinity of Falling creek, near Jamestown. The steady tide of European immigration in the seventeenth and eighteenth centuries caused a growing demand for bullets and stimulated further discoveries wherever the settlements of the colonists extended. The French acquainted the northwestern Indians with firearms, inducing them to hunt fur bearing animals on a large scale; consequently lead assumed a value in the eyes of the Indians, both for use in making bullets for their own weapons and as an article of traffic. Toward the close of the seventeenth century the Indians living in the region comprising portions of the present states of Wisconsin, Illinois, and Iowa, were melting lead and bartering it with the French traders. In the second half of the eighteenth century lead had become of such importance in the trade of the upper Mississippi country that it served as currency, the rate of exchange being a peck of corn for a peck of ore. In 1810 Nicholas Boilvin, United States Indian agent at Prairie du Chien, went on foot from Rock Island to the mouth of the Wisconsin, and reported that the Indians of the region had mostly abandoned the chase, except to furnish themselves with meat, and turned their attention to the manufacture of lead.

Previous to the Louisiana purchase nearly all the valuable lead mining lands were within the domains of France and Spain. Soon after these lands had passed under the jurisdiction of

the United States, congress, by the act of March 3, 1807, reserved all government lands bearing lead ores, and authorized leases of these lands. The first leases provided for a 10 per cent royalty on the lead produced; the rate was afterwards reduced to 6 per cent. No leases were issued until 1822, when crowds of prospectors began to enter this region. A few years later the mines gave employment to over 2,000 men, many of them farmers, who with their slaves spent only their spare time in the mines. The royalties were paid with some regularity for a short time only; after 1843, as a consequence of the immense number of illegal entries of mineral land at the Wisconsin land office, the smelters and miners refused to make any further payments, and the government was unable to collect any royalty from them. After much trouble and expense, it was, in 1847, finally concluded to sell the mineral lands.

The chief lead mining districts, which to-day furnish the bulk of the lead production of the United States, were not developed until much later. The lead deposits of the Joplin-Galena district, embracing southwestern Missouri and part of Kansas, were discovered in 1848, but attracted little attention before the civil war. The great western deposits of argentiferous galena were discovered in 1864, but could not be worked profitably until the extension of the railroads through that region.

The early methods of lead mining on this continent were extremely crude. The Indians, who during the time of the French dominion were the chief producers, only skimmed the surface, although occasionally they would drift for some distance into the sidehills, and when they reached rock would build a fire under it and crack it by dashing cold water on the heated surface. Their tools, in the earliest times, were buckhorns, many of which were found in abandoned drifts by the first white settlers, but in the eighteenth century they obtained iron implements from the traders to whom they sold their lead. The Indians loaded their ore in the shafts into tough deerskins, the bundle being hoisted to the surface or dragged up inclined planes by long thongs of hide. Many of these leads, abandoned by the Indians when the work of

developing them became too great for their simple tools, were found at a later epoch to be among the most profitable in the region.

Improvement in the method of working the mines was very slow for a long time after the advent of white miners. The first shaft in a lead mine in Missouri was sunk about the beginning of the nineteenth century. Schoolcraft, who visited the leading mining district in 1819, found about 40 mines, 4 or 5 of which had regular shafts. There was not an engine of any kind—horse, steam, or water power—for removing water from the mines, several of which, with the richest prospects in view, had been abandoned on this account.

The reduction of lead ore to the metallic state was in the earliest times not differentiated from mining. Any man who found a vein could mine and smelt the ore roughly himself. The methods of smelting were crude in the extreme. A hole was dug in the ground and lined with rocks. This was usually located on a hillside for the purpose of getting a strong air draft. Hollow log heaps were reared; the centers were filled with mineral; then as much wood as possible was piled on top of and around the heaps, and the mass was fired, with the result that a portion of the ore was smelted and ran into trenches in the ground. Sometimes this operation had to be repeated three times. Rough pigs run into a scooped out hollow in the earth itself, and weighing about 75 pounds, were usually made by the Indian squaws. This method of smelting was wasteful, but since the supply of ore was apparently unlimited the same practice was followed as late as the first quarter of the nineteenth century by white miners, as well as by operators who worked their mines with slave labor. About that time smelting began to be specialized by ore buyers as a separate occupation. The methods of reduction practiced in those days are thus described by Schoolcraft:

"Having raised a sufficient quantity of ore for smelting, the next process consists in cleaning the ore from all extraneous matter. This is done by small picks, tapered down to such a point that a careful hand may detach the smallest particle of adhering spar. It is necessary that the ore should

be well cleaned, for it would otherwise prove refractory in smelting. If there be any lumps of uncommon size, these are beaten smaller. The object is to bring the lumps as near as may be to a uniform size, so that the heat may operate equally in desulphurating the ore. It is desirable that the lumps should be about the bigness of a man's two fists, or about 15 pounds in weight; if too small, a difficulty and a waste is experienced in smelting. In this state the ore is conveyed to the furnace and piled on the logs prepared for its reception. When the charge is put in, which may in a common way be about 5,000 pounds, it is surrounded by logs of wood and covered over at the top and the fire is lit up at the mouth below. A gentle warmth is given at first, which is raised very gradually and kept at this point for about twelve hours to allow the sulphur to dissipate; the heat is then increased for the purpose of smelting the ore, and in twelve hours more the operation is completed and the lead obtained. Wood is occasionally added as the process goes on, and there is a practical nicety required in keeping the furnace in proper order, regulating the draft of air, etc., so that some smelters are much more expert, and thereby extract a greater quantity of lead from a like body of ore than others. This furnace is called the log furnace, and so far as I know, is peculiar to this country. It is of very simple construction, consisting of an inclined hearth, surrounded by walls on three sides, open at top, and with an arch for the admission of air below, and upon the whole it appears well adapted to the present situation and circumstances of the people. It is cheap, simple, may be built at almost any place, and answers the purpose very well. A good furnace of this kind may be built at an expense of from $50 to $60, every expense considered.''

It does not seem from this description that the white miners and smelters had by that time made much improvement upon the primitive methods of the Indians. It was not before 1836 that the log furnace was superceded by the blast furnace.

Ignorance of scientific methods caused the early miners to throw away the lead carbonate, or cerussite, which they

called dry bone and considered worthless. It accumulated in great heaps until the arrival, in 1838, of a German named Hagen, who knew the value of dry bone, and erected furnaces for its reduction. The result of the utilization of the cerussite was a largely increased production.

The ignorance of the practical miner likewise retarded the utilization of zinc ores, which are associated with lead ores and now constitute the chief value of the output of the zinc lead mines. The presence of zinc in the lead mines of the Mississippi valley was noted by Schoolcraft, who wrote as early as 1819: "Considering the rarity of this metal in America, and its extensive usefulness, which is yearly increasing, I have no doubt it will shortly attract the attention of some capitalist and become a source of much profit."

It took, however, more than half a century before the prediction was fulfilled. Whitney, writing thirty five years later, gave expression to the following view:

"No one acquainted with the manufacture of zinc ores into metal or oxide would recommend the establishment of works for this purpose in the western lead region, as the business can not be made profitable against the competition of the Belgian and Prussian manufactories, except under the most favorable circumstances of situation and an abundant supply of ore which can be obtained without any considerable mining cost. The zinc deposits of the west do not satisfy these conditions either as regards quantity or quality of the ore or of the proximity of fuel."

These words of one who was an expert in his own time have a peculiar sound to-day, when it is considered that over $8,000,000 is won annually from the western zinc deposits.

For over half a century zinc ore was taken out of the mines of the southwestern part of Missouri, in connection with lead ore, and thrown upon the dump pile as worthless. Mines were deserted because of the prevalence of this refuse, or tiff, as it was called by the miners. In the early seventies this peculiar looking substance, which was causing the lead miners so much trouble, was examined by a geologist and pronounced to be zinc ore. A carload of it was shipped to Lasalle, Ill., for treatment. The smelter returned $15 for

the carload, telling the shippers that it was a high grade of zinc ore. This led to further shipments of the ore. Abandoned mines were gradually reopened because of the zinc ore they contained, and at present the zinc product of Missouri is more than eleven times the value of all the zinc ore mined in the eastern states, where zinc mining dates back to 1848, and where the mines were the main source of the domestic zinc supply previous to the development of the Joplin-Galena district.

The last twenty years in the history of the lead zinc mining industry have been a period of change. Twenty years ago with a few exceptions all the mining was done by small companies, mostly unchartered associations of persons living in the immediate neighborhood. Some storekeeper, farmer, or local capitalist furnished the small amount of money needed for tools; and the men who worked in the ground in winter usually engaged in farm work during the summer. The ore was generally raised to the surface by a windlass, and cleaned by hand with a pickawee hammer, or crushed with a bucking iron on a flat stone, or by an itinerant horsepower crusher, and was concentrated by sluicing and hand jigging. The holders of lots sometimes put up crushing and washing machinery on their lots.

The smelting companies which drew their ore supply from this district had their resident or traveling purchasing agents. Most of the miners were poor and unable to work their diggings to good advantage, or to hold their ore long after it was cleaned.

The labor was to a considerable extent performed by miners working upon their own account. Men with no capital but their picks and shovels would lease small mining lots and try their luck. The advantages of the leasing system to the landowner and mine operator, as compared with the regular wage system, are further explained in the same article. The miners, working on their own account, with hopes of large ultimate gains, have every inducement to work hard and cheaply, and to follow every clew that working prospectors, who, during the season wander from place to place,

and follow every real or supposed indication of ore, may find.

How else, it may be asked, could prospecting be so well or so cheaply done? And there is a class of enterprising, skillful, well-to-do miners, naturally associated as partners, who have made one or more good strikes, and are always ready to take hold of any new venture that promises well, either in working a lot or in forming a land company to open new mines. Where else could be found capitalists so willing to risk their money in a speculative venture? Men of this sort are always ready and able to work themselves, or to direct the work above or below ground. How else could be obtained as willing and as watchful superintendents, foremen, and clerks?

The leasing system has maintained itself up to the present day in zinc mining. A comprehensive description of this system is given in a recent pamphlet by a local expert, Mr. Frank Eberle:

"The methods of mining and handling zinc ore are unlike those used in mining for other minerals. The first step necessary is to secure the land upon which to begin operations. Zinc mining lands are seldom sold, their owners preferring to lease them on royalty. Virgin lands, or those on which no mineral has been found, or which have never been prospected for mineral, are leased at 10 per cent royalty, that is to say, the landowner leases the land and agrees to take as payment one tenth of all the ore obtained from his land. The company or individual who secures the lease then divides the tract up into 1-acre mining lots and prospects the land with a steam drill in several places to ascertain whether the land contains mineral, and where the best bodies of ore are located, their depth, thickness, and the force of water that the miners will have to contend with. When the land has been sufficiently prospected, lots are then subleased to miners at 20 per cent royalty, which means that the miners must give 20 per cent, or one fifth, of the ore to the company or individual holding the original lease. Out of this 20 per cent the original lessee must pay the landowners 10 per cent, and generally he must also undertake to put in pumping plants, to keep the tract drained, where the water

is so strong as to interfere with mining. The miners lease one or more lots from the lessee of the tract, and begin operation by sinking a shaft.

"The zinc ore, or jack, is purchased at the mines by jack buyers representing American and European smelters. These buyers bid on the week's output of zinc ore. They make an offer of so much a ton for all of the ore to be taken out of the mine during the week. If the offer is accepted, the jack buyer sends his wagons to the mines, and hauls the ore to the cars for shipment to the smelters for which he buys. Every Saturday evening is settling up time. Then the mine owners, miners, and ore buyers assemble in the various towns in the district, and the ore buyer draws a check for the ore purchased from each mine. The check is made payable to the landowner upon whose property the ore was mined. He takes out his 10 per cent royalty, and passes the balance to the original lease holder, who takes out his 10 per cent royalty and gives the balance to the mine operator, who pays his operating expenses out of the share he receives."

The larger companies which have their own smelters buy all the ore from their lessees at a stipulated price, deducting from the same their royalties.

It is of great theoretical and practical interest to note the special conditions which have permitted of the survival of zinc lead mining on a small scale, and often with primitive methods, amid concentration of ownership in mineral lands.

The subject is treated from a technical point of view in the twenty second annual report of the United States geological survey, from which the following is quoted:

"The individual ore bodies are rarely large. The mines must accordingly be shortlived, and the plants must be built to meet that condition. In a district where it is cheaper to sink a new shaft than to tram ore 600 or 700 feet underground, central shafts of large capacity are out of place. Large central mills to which the ore of a whole tract is brought are not considered a good investment. In hauling 100 tons of 10 per cent ore 90 tons of waste drift are moved, and when simple and effective mills of small capacity are so easily and

cheaply built and run, individual mills are to be preferred, even though the larger mill be able to make a slight saving per ton in mill charges. It is difficult to supply dirt steadily enough to keep a large mill running, and loss of time is more costly with a large than a small plant. The mills of the district are very simple, and are developed on the principle of using a rougher jig before cleaning, instead of attempting close sizing. The result is a very great capacity at small cost. The saving is not so close as in a well run sizing mill, but the extra ore saved by the latter is not in this district worth the added cost of saving it. A hundred ton mill can be built in the district at a general price of $6,500 to $7,000, and the opening and equipping of a mine costs ordinarily, approximately, $10,000. The mill can be run by four men. To that number must be added a hoisterman and an underground force. The mill and plant are of such style as to be readily torn down and moved when the particular ore body is worked out, and the whole plant is designed for rapid work. Economy is sought in first cost rather than in refinements of efficiency. The whole style of equipment and the methods of mining and milling are designed to meet the conditions of shortlived individual deposits of low grade ore.

The higher cost of running small plants, as compared with mines operated on a large scale, comes from the expensive methods of generating and distributing power, but it is the opinion of Mr. Bain that, with modern methods of power transmission, this difficulty can be overcome by the development of central power plants.

Though the actual operation of the mines is to some extent still conducted on a small scale, the tendency toward combination has not been without effect upon the zinc lead mining industry. Both the productive capacity and the consumptive demand for spelter have been centralized in a striking manner. Upward of 50 per cent of the consumption of spelter in the United States is for the purpose of galvanizing iron, which business is now chiefly in the hands of the constituent companies of the United States Steel corporation. The manufacture of sheet zinc is in the hands of four com-

panies. The manufacture of brass in Connecticut, which is the principal center of that industry, is controlled by one company. The consumption of spelter for use in the de-silverization of lead is also chiefly in the hands of one corporation. It is safe to say, therefore, that 75 or 80 per cent of the demand for American spelter now comes from seven corporations. On the other hand, the production of spelter has also been centralized, practically the whole of the active smelting capacity being now divided among seven concerns.

METAL WORKING MACHINERY.

BY EDWARD H. SANBORN.

[Edward H. Sanborn, statistician; has had charge of important work in the United States censuses of 1890 and 1900, most of it being in connection with the manufactures division of the bureau; he was and is an expert in the iron and steel industry, and in the last census was in charge of the investigation into the use of power by manufactories.]

While the cost of some machine tools is higher now than it was five or ten years ago, the machine of to-day is the more economical because of its greater efficiency. The manufacturer who makes nothing but lathes, and manufactures 500 or 1,000 of them in a year, is able, as a rule, to build them better and more cheaply than the maker who builds only a few in a long list of other tools. Concentration on the details of a single kind of machine or tool has been productive of marked progress in construction, and has led to the gradual evolution of new and advanced types.

Specialization in the manufacture of machine tools has followed closely the differentiation of processes in other lines of industry, and thus there has been created a multitude of special machines, each designed to perform some single and often very simple operation. The bicycle industry furnishes a striking illustration of the readiness with which the machine tool builders met the demand for special tools to produce the various parts required in the construction of a bicycle. The advent of the chainless wheel called for a machine which would cut small bevel gears accurately, rapidly, and economically, and such machines were quickly forthcoming. This, indeed, is a characteristic tendency of the machine tool industry—the effort to create new types of tools which will do more and at less cost than can be done by any of the ordinary appliances at the command of the machinist.

Recent progress in machine tools and machine shop practice has been marked by the following significant features:

The automatic and semi-automatic principles have been extended to new and larger classes of work than before.

The forming tool has become a recognized shop appliance.

The oil tube drill has been developed from an exceptional to a regularly used tool.

Compressed air portable tools have been developed substantially de novo.

The application of the power press has been greatly extended.

Electrical driving has come into general use.

The system of heavy portable machine tools in conjunction with a massive iron floor plate has been originated.

The grinding machine has been largely increased in size, power, and extent of use.

Closely related to machine shop practice, though scarcely coming within machine tool classification, may be mentioned:

The development of traveling cranes.

The origin of high speed steels for cutting tools.

These lines of development may be discussed briefly in the above order.

The extension of the semi-automatic principle, as illustrated by the hand operated turret lathe, has been chiefly toward the execution of larger and heavier work, while the use of the entirely automatic turret lathe has been not only in the same direction, but has been adapted to entirely new classes of work. An illustration of the first line of development is found in several types of turret lathes which, although employing certain methods of attacking the work which were not known before their advent, is nevertheless essentially an extension of the turret principle to larger work than had before been done by it.

An illustration of the second line of development is to be found in the magazine feed full automatic turret lathe. Prior to the advent of this machine, the full automatic machine had been employed exclusively for making screws, studs, etc., from bar stock which was fed to the machine through the hollow live spindle, the pieces being first turned, threaded, etc., and then cut off, when the bar of stock was fed down-

ward and another piece made, the operation continuing until the bar of stock was used up. The new machine applied the automatic principle to the machining of parts which, when in the rough, were already in separate pieces, i. e., castings or drop forgings. In doing such work the finished piece must be taken bodily from the machine and a new rough piece inserted. This is a fundamentally different operation from merely pushing a long bar of stock to a new position. It is effected by the magazine feed, the magazine being filled with rough parts by the workman, these parts then being automatically inserted in the machine and removed therefrom when finished. The line of development exemplified by the machine first mentioned belongs to the entire decade, while that exemplified by the other belongs to its close.

Another line of development in this class of machines which should be mentioned is the use of multiple spindles, whereby the output of certain classes of work is very greatly increased—to the extent of a threefold ratio in some instances. An outgrowth of this development has been the making of small brass screws and similar articles without money consideration, the chips cut off in making the articles being accepted as sufficient payment for doing the work.

The use of the forming tool goes back of the last fifteen years, but its use prior to 1890 was chiefly, if not entirely, for the making of articles from very soft composition castings, examples of the work being seen in the caps of salt and pepper boxes. The application of the principle to harder material came about in connection with the bicycle industry, one of its final applications to articles of steel being in the making of bicycle wheel hubs. If this is not the first application of the method to steel, at least it familiarized the mechanical public with it, and from this it has come to have quite an extended application.

By the oil tube drill is meant a drill—either flat or twist—having an oil tube or oil channel leading to or near its point, through which a current of oil may be forced to lubricate and cool the cutting edges and to wash away the chips. It is used chiefly for deep drilling in steel and usually

in machines of the lathe class, in which the work revolves against a fixed drill, although the arrangement is also used in upright drilling machines, in which the tool revolves. The history of this appliance is almost exactly parallel to that of the forming tool. It was known and used to a limited extent before 1890, having been first used for the drilling of gun barrels; but its more extensive application must, like that of the forming tool, be credited to the bicycle industry, the development of the two tools being, in fact, simultaneous. The forming tool having been successfully applied to the machining of the outside of bicycle wheel hubs, it was found that a portion of the gain due to its faster action was lost because the simultaneous drilling of the hole required more time than the work upon the outside of the piece. This condition of things led to the adoption of the oil tube drill for this work, and from this application the use of the appliances has become widely extended. Of the two, the oil tube drill is no doubt the more important. The increasing use of hollow spindle lathes and automatic and hand operated turret lathes, in which the spindles are necessarily hollow, not to mention milling and other machines having hollow spindles, has given a wide field of usefulness to this tool.

The numerous class of small and unpretentious pneumatic tools which have very recently come into prominence and extended use may, it is quite possible, be looked upon as the most important single machine tool development of recent years. Of these, the first in order of importance as well as of time is the pneumatic hammer. Originally devised as a substitute for the hand hammer and chisel in the machine shop and in stonecutting, it has extended its field of usefulness to many other fields, and is to-day an indispensable tool in shipbuilding and in the erection of steel frame buildings. Of the general class of compressed air tools, the next in importance to the hammer is perhaps the rotary drill, which, in its numerous forms and applications, has introduced mechanical power in place of hand labor for classes of work to which the application of mechanical power seemed almost hopeless. These and numerous other applications of compressed air to machine and similar work stand almost wholly

to the credit of the last fifteen years, the hammer alone having been in use prior to 1890.

The great expansion in the use of power presses which has recently taken place must be credited largely to the growth of the electrical industries. The advent of the laminated armature for electric generators and motors called for accurately made punchings of sheet metal of a size and in numbers previously unknown. The power press furnished the natural method of making them, and in its development the capabilities of the machines were demonstrated as they had never been before.

The electric motor as a means of driving machine tools was first seriously proposed about ten years ago, and was generally looked upon by mechanical men as a fad of the electrician. The innovation nevertheless obtained a foothold, and advantages which were not foreseen were found to attend it. It has become the accepted method of driving factories which are composed of many departments, the flexibility and economy of the system in distributing power over a considerable area from a central station being here the factor of dominating importance, and those which are of a nature requiring tools and machines to be located at considerable distances apart, especially if they are also to be intermittently operated. It is also making rapid progress in machine shops, to which the above limitations do not apply, though in such applications opinion regarding its merit is still unsettled. A leading controversial point is the attachment of individual motors to each machine tool versus group driving of several machines through a single motor and a line shaft. There are well defined conditions under which each method is suitable, but there is still a wide intervening field of debatable ground. As a matter of fact, in this field the individual motor is making rapid progress —more so perhaps than can be readily explained.

Like the increased development of power presses, the floor plate portable tool system of attacking heavy work must be credited to the electrical industries, which in this instance, curiously enough, furnished both the work for which the system was first devised and the means for doing the work. It was the machining of the ring or magnet frames of large electric

generators to which the system was first applied, and the electric motor supplied the only practicable method of driving the tools which form part of the system. The system has not yet found much application outside of electrical works, although a beginning has been made, and this growth will doubtless continue.

The grinding machine was first devised during the last fifteen years as a means of doing superior work, but it was not long before it became evident that it was a source of economy as well as a means of securing superior workmanship. The full significance of this was, however, slow to be realized, and it was not until toward the close of the decade that the movement began toward a very marked increase in capacity, weight, and power of the machine.

In no feature of machine shop practice has there been greater progress in American shops than in the provision of crane facilities. Twenty years ago the absence of these facilities was a national reproach, but to-day there is undoubtedly better crane service in the United States than exists elsewhere. This development is to be credited to the electric motor, without which it is at least doubtful if the present stage of progress could ever have been reached. The mere transmission of the power required for cranes of present capacities by the old square shaft or flying rope would be a serious problem. Electricity furnishes, in fact, an ideal method of driving cranes, and the necessary installation of an electric plant for operating cranes has no doubt greatly furthered the adoption of electric power for other purposes.

Within the last few years discoveries have been made whereby certain classes of tool steel are made to endure cutting speeds which before were impossible. Like all other useful things these steels have certain limitations and it is too early to state definitely what their ultimate economic importance will be. It is reasonably certain, however, to be considerable.

QUICKSILVER.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York city in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

Mercury, or quicksilver, has been known to mankind from very early times. No mention of it appears, however, in the books of Moses or in the works of the early Greek writers. The earliest known reference is in the writings of Theophrastus (300 B. C.), who speaks of liquid silver or quicksilver. Dioscorides refers to artificial mercury as water silver; Pliny gave it the name of hydrargyrum in contradistinction to native mercury, which he called argentum vivum. The name quicksilver was undoubtedly suggested by the liquid form and silver color of the metal, while that of mercury was derived from the name of the Greek god Mercury, probably in allusion to the quickness and ease with which it flows in any direction. The salts of mercury also were known at a very remote period. The early Arabians were familiar with mercurous chloride (Hg_2Cl_2), or calomel, and murcuric oxide (HgO), the red oxide, and the alchemists possessed a knowledge of mercuric chloride ($HgCl_2$), corrosive sublimate. The mineral cinnabar, mercuric sulphide, has been used as a pigment from the most ancient times on account of its enduring vivid red color. By reason of its peculiar physical properties in being liquid, very heavy, and not acted on by air, sulphuric acid, or hydrochloric acid, mercury perhaps more than any other metal has excited the attention and curiosity of experimenters.

The symbol of mercury (Hg) is derived from the old Latin

name hydrargyrum. Its atomic weight is 199.8. Aside from bromine, mercury is the only elementary metal which exists in a liquid form at ordinary temperatures. It is a bright tin white liquid, and, when free from impurities, the globules retain a perfectly spherical shape. The luster is mirror like, and like that of silver it is preserved in air free of sulphurous gases. Mercury, when cooled to a temperature of –38.8° C., is transformed into a tin white, ductile, malleable mass, softer than lead and crystallizing in octahedrons. During the cooling it contracts uniformly until the temperature of solidification is reached, at which point a considerable contraction takes place, and, as a consequence, the solidified mercury will sink below the surface of liquid mercury. At 0° C. the specific gravity of mercury is 13.596 and at –38.8° C. the specific gravity of solidified mercury is 14.193. In very thin films the liquid metal is transparent and of a violet blue color when viewed by transmitted light.

The specific heat of solidified mercury (between–78° C.and–40°C.) is 0.0247; that of liquid mercury (between 0°C. and100°C.) is 0.0333. Its thermal conductivity is 667, compared with that of silver taken at 1,000, and its electrical conductivity at 22.8°C. is 1.63, silver at 0°C. being taken at 100.

The boiling point of mercury at the standard pressure of 760 mm. is 357.25°C. Above this temperature it becomes a transparent, colorless vapor, having a density of between 6.7 and 7.03, referred to air as a unit. The density of gaseous mercury compared with hydrogen is 100.92, and as its atomic weight is 199.8, this element in a gaseous form consists of monatomic molecules. Mercury gives off vapors at all temperatures. This may be illustrated by suspending a piece of gold leaf above the surface of mercury in a stoppered bottle; the gold leaf will slowly assume a white color from the formation of gold amalgam on the surface.

In its liquid and gaseous forms mercury is poisonous, producing salivation when taken either internally through the lungs or stomach or by absorption through the pores of the skin. Mercury is not tarnished by exposure to the air, nor is it acted on by many gases; hence it is an invaluable

aid to the chemist in the collection and measurement of gases which are soluble in or absorb water. When subjected to prolonged heating in the air, mercury is slowly transformed into red mercuric oxide (HgO), which at a higher temperature is again decomposed into its elements—mercury and oxygen.

Liquid mercury is converted by agitation with oil or by trituration with sugar, chalk, or lard into a dull gray powder. This process is called deadening, and is used to prepare mercurial ointment, the gray powder consisting simply of very finely divided mercury in the form of minute globules.

In commerce mercury is usually contaminated with a small proportion of dissolved metals, which cause a globule to lose its spherical shape and drag a tail behind it while flowing over an inclined surface. If the mercury is shaken in the air, these metallic impurities become oxidized and form a black powder or scum, which incloses small drops of the metal, thus preventing them from coalescing. Mercury in this condition is said to be floured. Commercial mercury is best purified by distillation, but for ordinary purposes the impurities may be removed almost entirely by repeated agitation with dilute nitric acid or perchlorate of iron, either of which atttacks the impurities and forms with them soluble nitrates and chlorides, respectively, which are removable by washing with water.

Mercury is found in nature chiefly as the ore cinnabar, mercuric sulphide (HgS or Hg_2S_2). It occurs also, though less commonly, as native mercury, which is disseminated in many cinnabar deposits in the form of fine globules, sometimes in large quantities. From a commercial standpoint, cinnabar and metallic mercury are the only ores of importance.

With most metals mercury forms a series of alloys called amalgams; in some cases, as with the alkali metals, the formation of the alloy is attended with a rise of temperature, while in other cases, as with tin, an absorption of heat results. Sodium and potassium amalgams are decomposed by contact with water; yielding hydrogen gas and an alkaline hydroxide; for this reason sodium amalgam is used in the laboratory as a reducing agent. Zinc amalgam is acted upon very

slowly by dilute sulphuric acid, and on this account the surface of zinc plates in galvanic batteries is usually amalmated. Tin amalgam is used to produce the reflecting surface of ordinary mirrors, and amalgams of gold, copper, and zinc are used in dentistry as fillings for teeth.

In addition to the amalgams, mercury forms the following commercially important compounds: With chlorine, mercurous chloride ($HgCl$), or calomel, largely used in medicine, and mercuric chloride ($HgCl_2$), or corrosive sublimate, used in medicine and in surgery as an antiseptic, and also in the preparation of anatomical specimens, and in the dressing of furs and skins; with oxygen, mercurous oxide (Hg_2O), the suboxide or gray oxide of mercury which is of little importance commercially, and mercuric oxide (HgO), the red oxide of mercury or red precipitate, used in medicine and for various other purposes in chemical analyses; with sulphur, cinnabar, mercuric sulphide (HgS), or vermilion, the same as cinnabar, the chief ore of mercury.

Vermilion is invaluable as a pigment, because of the permanence of its vivid cochineal red color. It is made artificially in two ways—one, termed the dry method, in which an intimate mixture of metallic mercury and sulphur in proper proportions is heated in a retort and the sublimed product condensed and ground very fine, the beauty of the tint depending largely upon the fineness of the material; and the other, called the wet method, by which various compounds of mercury are transformed into the sulphide by the use of chemical reagents. Vermilion prepared by the wet method is of better quality than that made by the dry process. The manufacture of vermilion has declined in recent years on account of the competition of cheaper pigments which have supplanted its use. The most important of these is orange mineral (red lead), which is toned up to the proper color by the use of eosin, one of the aniline dyes. These imitation vermilions are now employed for almost all of the more common uses, such as wagon painting, and while they are inferior to the true mercury vermilion, from the fact that they fade on exposure, yet they are a fairly satisfactory substitute as long as they are protected by an ex-

terior coating of varnish. Mercury vermilion is now used chiefly for red colors in oil paintings, lithography, etc.

Mercury is extracted by heating the ore in a retort or a furnace; the metal is expelled as a vapor, which is subsequently condensed in cooling chambers and collected.

Up to the present time mercury has been extracted from its ores solely by the dry process. Various chemical and electrolytic methods have been proposed repeatedly and numerous experiments made, but without commercial success.

Perhaps the development of electric current generated by water power in localities where the use of fuel is nearly or quite prohibitive will render profitable the extraction of the metal by some electrolytic process.

The principal ore of mercury is cinnabar, mercuric sulphide, accompanied at times with minute globules of native mercury. The metal may be extracted from the ore by a simple distillation, either in a retort or in a shaft furnace, and though mercury may be separated from cinnabar in numerous ways, only two methods are now used on a large scale. One is based on the decomposition of the ore at a high temperature by air, forming metallic mercury and sulphur dioxide gas in accordance with the reaction: $HgS + O_2 = Hg + SO_2(360°C.)$. The other accomplishes the decomposition by the use of lime or iron which combines with the sulphur and sets free the mercury in accordance with the reactions: $4HgS + 4CaO = 4Hg + 3CaS + Ca \times O_4$, and $HgS + Fe = FeS + Hg$, respectively. These chemical decompositions take place at temperatures above the boiling point of mercury so that the latter is expelled in gaseous form and subsequently condensed and collected in cooling chambers.

The most important commercial use of mercury is in the extraction of gold and silver from certain ores by the amalgamation process; the precious metals becoming alloyed with the mercury, form a heavy amalgam, which is separated by gravity from the fine sands and the tailings of the ore suspended in water. Owing to the avidity with which mercury combines with impurities, thereby becoming subdivided into innumerable minute globules which will not coalesce, considerable quantities of the metal are lost during

the amalgamation process, by being held in suspension in the water, and washed away with the sands and the tailings.

In the chemical industries large quantities of mercury are used as electrodes in several electrolytic processes, notably in the electrolysis of brine to form sodium salts. The solution of salt having been decomposed by the electric current, the metallic sodium thereby set free at the cathode immediately combines with the mercury, from which the sodium is subsequently extracted by a treatment with water, forming sodium hydroxide (caustic soda). On account of its high specific gravity, and its freedom from attack by many gases, mercury is an invaluable material for the construction of liquid seals in gas collecting apparatus, for making thermometers and barometers, and for making electrical contacts in certain apparatus used in physical laboratories and industrial processes.

The quicksilver deposits of commercial importance in California are situated in the coast range and are limited to an area bounded by Trinity county on the north and San Luis Obispo county on the south, both counties being included. During 1902 San Benito county contributed 7,289 flasks, valued at $306,096, the product being derived largely from the New Idria mine. In Napa county the chief producer is the Napa consolidated mine at Oat Hill. In the Knoxville district the Boston mine, formerly the Readington mine, under the control of the Boston Quicksilver Mining company and the Manhattan mine contributed to the output. The total production for Napa county during the year amounted to 7,300 flasks. Santa Clara county was next in the order of quantity produced, contributing 5,779 flasks. The chief producer in this county was the New Almaden mine, followed by the Guadalupe mine. The New Almaden mine is the oldest quicksilver mine in the United States. It was discovered and worked in 1824, when California was under Mexican rule, and was then known as the Chaboya mine. Later it was abandoned until 1845, and since 1850 it has been worked continuously.

As to the future of the quicksilver mining industry of California the larger and better known mines have in a measure

been worked out, and it is hardly within the range of proba-
bility that other mines equal in extent to the New Almaden
or the New Idria will be discovered. Yet, on the other hand,
there are many smaller mines which, by contributing from
20 to 300 flasks each per month, supply a considerable quan-
tity of metal in the aggregate. Furthermore, the improve-
ment in metallurgical and mining practices during recent
years, which permits the profitable treatment of very lean
ores, will probably maintain the quicksilver industry in an
important economic position for many years to come. It is
stated in general that quicksilver can be produced in California
at a mining and smelting cost of $3 per ton of ore, which ren-
ders it possible to treat with profit ores containing from 0.3 to
0.6 per cent of quicksilver; in a few cases it is possible to treat
even lower grade ores and yet make a profit. The general
statement is made that a modern furnace, operating on average
ores, produces quicksilver at a cost of $35 per flask not in-
cluding interest on capital invested in the plant and property,
or the cost of development work at the mine.

In Oregon the sole producer of quicksilver in recent
years has been the Black Butte Quicksilver Mining company,
which opened a quicksilver mine in 1898 on a spur of the
Cascade mountains at Black Butte, Lane county. A modern
40-ton shaft furnace of the inclined shelf type was installed,
but after a few months it was closed for alterations, the con-
densation of the quicksilver being too imperfect to render
the smelting profitable. Operations were resumed in 1900.

The principal operating companies in Texas are the
Marfa and Mariposa Mining company, with three 10-ton Scott
furnaces; the Terlingua Mining company, with one 40-ton
Scott furnace; and the Colquit-Tigner Mining company, with
one 10-ton Scott furnace.

The cinnabar deposits of California Hill, Brewster county,
near Terlingua post office, 90 miles southeast of Marfa, were
known to the Comanche Indians, who used them as a ver-
milion pigment. The knowledge of these deposits, however,
was not recorded until 1894, when several Mexicans found
a few pieces of cinnabar float and took them to San Carlos,
on the Mexican side of the Rio Grande, whence they were

sent to Chihuahua, and their mineralogical character determined. Mr. George W. Wanless, of the Rio Grande Smelting works, and Mr. Charles Allen, of Socorro, N. Mex., under the direction of the Mexicans, found the veins and located the first mineral claims. Shortly after this Prof. William P. Blake described these deposits under the title Cinnabar in Texas, the first important article concerning this subject on record. Considerable prospecting work was carried on in the district, but it was not until 1898 that the metal was produced in commercial quantities.

The deposits of cinnabar at Terlingua are of two classes; one occurs in hard and durable limestone and the other in soft and friable argillaceous beds. The ores are cinnabar, mercury, yellow sulphide, and terlinguaite, and contain in addition several other mercury minerals, such as calomel, eglestonite, and montroydite, which, on account of their rarity, are of scientific interest only. Cinnabar is the principal mineral and is usually mixed with clay or iron oxide. Native mercury is present in several localities in the district, occurring in the interstices of crystalline calcite, and a single cavity in the calcite veins has yielded as much as 20 pounds of the native metal. The associated gangue is composed of calcite, aragonite, gypsum, and occasionally a little barite; iron oxide, pyrite, and occasionally arsenic and manganese minerals.

PLATINUM.

BY DAVID T. DAY.

[David T. Day, chief of the mining and mineral resources divisions of the United States geological survey, born East Rockport, Ohio, 1859; educated in Johns Hopkins university; has compiled the official reports on the mineral resources of the United States since 1885 and has represented the United States at the principal international expositions and been on a number of the juries of award.]

At the time of the eleventh United States census platinum was known to occur in the United States in the following localities: California—Butte, Del Norte, Humboldt, Mendocino, Plumas, Sierra, and Trinity counties; Idaho—Wood river country; New York—near Plattsburg; North Carolina—Burke and Rutherford counties; and Oregon—Coos, Curry, Josephine, and Lane counties. In addition to these localities in the United States, there was a platinum product greater than that from the United States which helped to supply the American market from the region of Granite creek, British Colombia, and the copper ores from the Sudbury district of Canada also brought in some platinum and palladium in the nickel copper matte imported into the United States.

Associated with these platinum ores were occasionally found the allied metals—osmium, iridium, and palladium.

About 1898 the demand for platinum became more considerable and the search for it, and especially for the allied metal osmium, became vigorous. It resulted in much prospecting in the eastern states, as well as in the west, and many assays of supposed platinum ores, made by Mr. A. W. Johnston, showed that certain rocks in eastern Pennsylvania, eastern New York, and in many other localities contained traces of platinum.

The one event of importance in the development of the platinum industry in the United States was the discovery by Dr. L. D. Godshall, manager of the Boston and Wyoming smelter, at Encampment, that the copper ores and matte of the Rambler mine, Grand Encampment district of Wy-

oming, contained platinum and palladium. These obser-
vations were confirmed by Professors Wells and Penfield,
of Yale university, who separated sperrylite (platinum diar-
senide) from this Rambler ore. Further investigations
by Mr. Johnston and Professor Kemp showed that the ore
of the Rambler mine contains platinum intimately mixed
with all the copper ores and even the chalcopyrite, which
apparently was the original copper ore in this mine, also con-
tains platinum. This confirms an observation of the writer
in 1899 to the effect that platinum occurs in the pyrite grains
found in certain hydraulic mines on the Trinity river in Cali-
fornia, notably in the mine of F Huertevant. These ob-
servations have led the searchers for platinum to examine
a great many deposits of pyrite in the United States with
the hope of finding them commercially rich in platinum, how-
ever, without commercial result, so far as the writer is in-
formed. This work is referred to, however, as indicating
a direction of search for platinum which may yet prove
profitable.

At the time of the twelfth census, therefore, the supply
of platinum to the United States market, in addition to the
importations from Russia and small importations from South
America, consisted in the supply of platinum obtained from
the localities in California and Oregon mentioned above, a
small product from the Granite creek district, British Colum-
bia, and a more considerable product obtained in refining
the nickel copper matte from the Sudbury district of Canada.

From the domestic ores in the United States the product
during 1902 was 94 ounces, valued at $1,814. This was
obtained as a side product in placer gold mining, and as the
production is entirely dependent upon the more important
production of gold this great decrease in the quantity of
the platinum produced, as compared with 1,408 ounces in
1901, is easily understood. In fact, the product during the
last few years has varied most widely both in quantity and
in the value of the product. The variation in value has been
due not only to the real fluctuation and gradual increase
in the price of refined platinum, but particularly to the fact
that the value given has been that of the crude grains as col-

lected and which vary widely in their contents of pure platinum. In addition to the platinum product of 1902, 20 fine ounces of iridium were obtained. In 1901 the corresponding product was 253 ounces of iridium.

Of the total production of platinum in the world, about 90 per cent comes from Russia, with the remainder divided among Colombia, South America; New South Wales, Australia; the United States, and Canada. The average annual product in Russia was 104,023.6 ounces for the ten years 1881 to 1890, inclusive, and 183,376 ounces for the eleven years 1891 to 1901, inclusive.

Since the close of 1899 th e price of platinum has steadily increased, reaching its maximum value in January, 1902, when the price in New York was $20 to $21 per ounce for ingot platinum. The price fell to $19.50 in February, and in June to $19. Osmiridium is quoted at from $6 to $10 per ounce. This gradual increase in the price of platinum during the last ten years is due to the fact that there has been found no metal or alloy which will take the place of platinum, and also to the fact that there is such a limited supply and increased demand.

GRAPHITE.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York city in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is the assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

The name graphite is derived from the Greek γράφειν, to write, and refers to the use of the mineral for that purpose. Graphite is sometimes called plumbago or black lead, because of its lead like appearance, although it contains no lead. Graphite was known to the ancients. Up to the latter part of the eighteenth century, however, the names plumbago and molybdena seem to have been applied indiscriminately to graphite and to molybdenite (molybdenum sulphide, MoS_2), both of which leave a black mark when rubbed on paper. Graphite appears to have been first distinguished as early as 1565, by Conrad Geissner, but the popular misconception as to the two substances prevailed until 1779, when the famous chemist Scheele showed them to be entirely distinct.

Graphite occurs as a form of carbon, and constitutes the last stage in the mineralization of vegetable matter. In the first stage of this process the woody tissue is converted into peat; the peat to a lignite; the substance then passes through the range of bituminous coals to semianthracite, anthracite, graphitic anthracite, and finally it is converted into graphite, which is practically pure carbon. There is no strict line of demarcation between these various forms of carbon, which merge gradually into one another. In structure and purity, specimens from different deposits show a wide divergence.

The mineral occurs in two forms, the crystalline and the amorphous. Crystalline graphite is usually found in a compact foliated or granular mass. At times the crystals are in the form of distinct hexagonal plates. The amorphous variety is, as its name implies, without crystalline structure, The term has been used to include a wide range of natural carbonaceous products—such as the graphitic anthractie of Rhode Island, which is of a structure between scaly and granular, and selected samples of which contain as much as 52 per cent of carbon; and the so-called Baraga graphite of Michigan, which in reality is a carbonaceous schist. The crystalline variety consists of finer grades, and hence is used where softness and a smooth uniformity of structure are desirable, as for lubricants or in the better grades of pencils. Graphite is iron black or steel gray in color and has a metallic luster; to the touch it is smooth and soap like. Its specific gravity varies from 2.015 to 2.583, the variation being due to the impurities—such as iron oxide, alumina, magnesia, lime, and silica—which are present in all natural graphite. Usually, there is also from five tenths of 1 per cent to 1.3 per cent of hydrogen—a fact which seems to point to an organic origin. Graphite is infusible, and resists the corrosive action of many chemicals and molten metals. These properties render the crystalline variety, with its flake like form, of great value in the manufacture of graphite crucibles for special purposes— for instance, to resist intense heat in the manufacture of crucible steel; to possess great density at a high heat, as in the refining of gold and silver; and to resist the corrosive action of easily oxidized metals and alloys in a molten condition, as in melting brass, bronze, etc. Although crystalline graphite will burn in oxygen at and above a temperature of 575° C., it is a good conductor of heat and electricity; this property renders it of special value for the manufacture of the commutator brushes used in electrical machines, for use in electroplating, and for electrodes in many electrolytic chemical processes.

In its chemical relations, graphite occupies a position distinct from that of any other form of carbon. The most striking difference is the effect of treatment with fuming nitric

acid and potassium chlorate; diamond is unaltered, and amorphous carbon (charcoal) is completely dissolved, but graphite is converted into a compound known as graphitic acid or graphitic oxide $(C_{11}H_4O_5)$.

As a fact of mineralogical interest, but one which has no industrial importance, it may be mentioned that meteoric masses have been found containing graphite which in its properties resembles the graphite formed during the cooling of high carbon and pig iron.

Crystalline graphite is widely distributed throughout the United States, but the known deposits of sufficient extent and purity to warrant working on a commercial scale are few in number. During the past decade the domestic output of high grade crystalline graphite has been obtained chiefly from the mines near Ticonderoga, Essex county, N. Y. The mines in Chester county, Pa., were reopened in 1897, after a long period of inactivity, and have been in continuous operation since that time. In 1899 the mines in Clay county, Ala., produced a small amount. There has been considerable activity in the exploitation of graphite properties in Bartow county, Ga.; near Dillon, Beaverhead county, Mont.; in Merrimack county, N. H; in McDowell county, N. C.; at Bloomington, in northern New Jersey; and in many localities in California; but up to the present time the work has been confined chiefly to determining the character and extent of the deposits, and to ascertaining by experiment the best method of concentrating the ore so as to convert it into a salable product. The limited number of graphite mines now producing the crystalline variety of the mineral bears witness to the difficulties encountered in the development of a prospect into a paying property.

The principal mines in New York are at Ticonderoga, Essex county. The graphite is of the foliated variety, occurring in minute scales in the cleavage planes of a seam of gray quartzite. The ore contains an average of 10 per cent of graphite, of which but little more than one half is extracted by the prevailing method of working. The graphite bearing bed lies between strata of massive micaceous gneiss,

garnetiferous gneiss, and light colored quartzite entirely free from graphite.

There are numerous limestone deposits in Essex and neighboring counties of New York which contain graphite disseminated throughout the mass, or in small lenses of very rich ore. While a number of these deposits are being promoted and developed, the only ones of apparent promise are on Lead hill, back of Ticonderoga, and on Warner hill, between Ticonderoga and Crown Point. It is probable that if any more valuable mines are opened in this section they will be in the graphitic quartzite, as the lenticular bodies in the limestone have proved uncertain.

In Pennsylvania the principal graphite mine is one mile east of Chester Springs, Chester county. The mineral occurs in two layers of disintegrated mica schist, one 4 feet and the other 6 feet in thickness. Adit levels have been run in on the hillside, following the layers, and the rock is so disintegrated that most of the ore can be removed by pick and shovel without recourse to blasting. At the mill the ore is crushed in rolls and cleaned in a log washer of the type commonly used at clay works. After being washed it is again ground, refined by pneumatic concentration, and screened into different grades. There are other graphite properties in the state, notably at Byers, several miles below Chester Springs, and at Pikeland, both in Chester county, and also at Mertztown and Boyertown, Berks county. These properties have been productive at various times, but for the most part are now inoperative. The existence of graphite throughout a large part of the ridge extending from Phoenixville to the Brandywine river seems very probable. Occasionally pockets are found which yield nuggets and masses of nearly pure graphite, such as formed the basis of the producing mines in this region, but more often the mineral is associated with iron oxides, quartz, and feldspar, so that the extraction of the graphite involves considerable difficulty.

The increased demand for crystalline graphite has led to a careful study of the concentration of low grade graphite disseminated in flakes. Operative plants have changed and

improved their methods, and new concentrating processes are being tested.

There are two common methods of concentrating crystalline graphite from its ore—the wet and the dry. The wet or water method has been developed to a marked degree of efficiency, and is the one now generally used. The mode of procedure is to crush the ore wet, and separate coarsely by stationary buddles, the concentrates being dried and further treated with buhrstones and screens. No mill, however, has adopted either method in its entirety, because the specific gravities of the constituents of the ore vary so little. Several pneumatic processes have lately proved a partial success, but they have been of limited application, on account of the impossibility of removing the small scales of mica which occur in some of the deposits.

Two new features in concentration practice, in both of which the older method of complete submersion beneath the surface is replaced by flotation, are worthy of note—first, the use of petroleum vapor, which, being readily absorbed by graphite, permits the flakes to be more readily separated from the gangue material by flotation; and, second, the heating of the ground product before separation, which makes the flakes of graphite so light that they float on the surface of the water, whence they are removed.

The incentive to develop properties containing amorphous graphite is much less than in the case of the crystalline variety. On account of the limited use of the former, the value of the crude product is only from one eighth to one tenth of that of the latter. For the manufacture of graphite crucibles and for many electrical purposes no satisfactory substitute for crystalline graphite has been discovered, while in the case of amorphous graphite there are many other materials of equal suitability for its various uses.

The mining of amorphous graphite in the United States has been of comparatively recent development. During 1902 the product was obtained chiefly from Wisconsin, followed by Michigan, Rhode Island, South Dakota, Wyoming, and New Mexico, in the order named. There are numerous

deposits in other states, but none in sufficient quantity or purity to be of commercial value at the present time.

In Wisconsin the mines near Stevens Point, Portage county, produce graphite which is reported to contain, at times, as much as 74 per cent of carbon. It is utilized in the manufacture of paint, lubricants, and greases.

In Michigan there are several thousand acres in Baraga county, composed of a carbonaceous schist without a sign of a vein of graphite. This material is ground for paint and is improperly called graphite.

In Rhode Island the mines near Cranston have been operated for many years. The graphite shows a structure between scaly and granular, and the grade of the product has not until recently exceeded 55 per cent of carbon, the remainder of the ore being silica and iron oxide, with a trace of sulphur.

In South Dakota there are several graphite properties in the vicinity of Custer containing promising veins of graphite, one of which is reported to be 4 feet in width and of high grade mineral. At Castle Creek, in Pennington county, 25 miles northwest of Custer, there is a vein which is reported to contain 40 per cent of carbon and to be in contact with a 10-foot layer of graphitized slate.

In New Mexico considerable exploratory work has been done at the graphite properties 8 miles southwest of Raton, Colfax county.

In Ceylon, which is the chief producer of high grade crystalline graphite, the main deposits are in the western and northwestern provinces. The graphite, which is scaly or fibrous in structure, is found in veins of irregular occurrence and extent, which break through crystalline rocks of the character of granulite. The minerals associated with graphite in the material which forms the vein are feldspar, rutile, pyrite, biotite, and calcite. The country rock is often highly decomposed, and then consists mainly of kaolin and similar decomposition products. The formation of graphite in these deposits has been attributed by Dr. Ernst Weinschenk to the decomposition of vapors carrying carbonic oxide and cyanogen compounds.

In one of the Ceylon mines near Caltura the graphite occurs in a series of veins in gneiss which has become converted to a depth of 36 feet, into a mass resembling laterite. The indications point to the deposition of the carbon by the decomposition of hydrocarbon vapors, forming a true vein.

The Ceylon mining industry, which is entirely in the hands of the natives, has been profitable for many years, chiefly on account of the purity and consequent high value of the product. The method of mining is extremely primitive. A shaft is sunk to the level of the ground water (from 40 to 200 feet), and drifts are cut from the bottom of the shaft until the air is so bad that the lamps of the miners will no longer burn; the ground is then stopped upward, the waste being dropped behind until the shaft is filled. In some cases the veins are followed by open cuts and galleries. The underground workings are roughly timbered, and powder is used to break the rock. The ore is hoisted by windlass and bucket, or passed out by hand. A peculiar feature of the industry is the opposition to the installation of modern mining machinery and methods, on the ground that the new conditions might be less satisfactory than the older and fairly profitable ones. The mined product is famous for its purity, the analysis of several samples showing a carbon content of from 99.283 to 99.792 per cent.

In Austria graphite occurs in the provinces of Bohemia, Styria, Moravia, Carinthia, and lower Austria. The chief producing mines are at Schwarzbach, in Bohemia. The deposits, which are lenticular, occur in gneiss, in parallel beds, extending over an area 14 miles long by 10 miles wide.

In Styria, which ranks second in importance, there is found a highly metamorphosed system of carboniferous shales, clay slates, limestones, and conglomerates with coal seams, the coal of which has passed into graphite. It is very compact, very pure, and often extremely hard, in some cases retaining exactly the appearance of the coal from which it has been derived. The graphite region extends from Leoben to St. Lorenzen, a distance of 25 miles. The most important deposits are at St. Michael, where five parallel beds, varying in thickness from a few inches to several feet, and occurring

in grayish black schist, have been exploited for a length of over 600 feet. The preparation for market consists in simple screening. The product, which contains nearly 80 per cent of carbon, is used in making graphite crucibles.

Other graphite deposits are found in lower Austria, Moravia, and Carinthia; but the mineral, which is associated with granular limestone in gneiss, and is usually amorphous and friable, is too impure to warrant working commercially.

The graphite deposits of Germany are confined to the easternmost corner of Bavaria. In a region bounded on the south by the Danube and on the east by the Austrian frontier are gneisses and gneissose rocks impregnated with scaly graphite. In some places—chiefly in the immediate neighborhood of intercalations of granular limestone, altered by contact metamorphism—the mineral occurs in lenticular masses, rich in carbon. Both the graphite-bearing rock and its near neighbors are highly decomposed, so that kaolin and other decomposition products are found in intimate association with the graphite deposits. The lenticular form of the deposits, their geological relationship with limestone intercalations, and their frequent association with kaolin and other decomposition products connect them closely with the Bohemian type, from which they are differentiated by the less compact and more crystalline character of the graphite. The genetic connection between the Passau and Ceylon types is very close.

At Borrowdale, England, fine-scale graphite was at one time found in veins in greenstone porphyry. The gangue material was chiefly calc-spar, brownspar, and quartz, containing nests and lumps of very fine graphite, especially suitable for the manufacture of pencils. These mines, however, have been exhausted.

The mines at Batugol, province of Irkutsk, Siberia, also are practically exhausted. The graphite was finely fibrous and purer than that at Borrowdale. The veins run through a granite or dioritic rock, while in the closely adjoining limestone (altered by contact metamorphism) are great lumps of pure graphite, suitable only for pencils.

Graphite can be made artificially in several ways, among which are the following:

(1)   In the production of cast iron from ore containing a large proportion of carbon, by allowing the molten mass to cool slowly.   As cast iron can retain in combination a much larger proportion of carbon when molten than when solid, the cooling of the mass causes the carbon to separate out, forming scales of graphite disseminated throughout the iron. It is to the presence of the scales of graphite that gray pig iron owes its peculiar properties and its gray color.   When this form of pig iron is dissolved in acid, the scales of graphite remain as an insoluble residue.   When cast iron is kept in a molten condition for a long time, as in the manufacture of converter steel, scales of graphite collect on the surface of the molten metal, forming so-called kish.   This source of artificial graphite is of no commercial importance.

(2)   By the reaction or decomposition of various chemical compounds containing carbon, notably the cyanide class of salts.   Graphite can not be produced commercially from chemicals on account of the excessively high cost.

(3)   By the treatment of certain carbonaceous materials in the electric-arc furnace, which is the process now used on a very large scale.

Pure graphite has many valuable properties, such as high electrical conductivity, great resistance to chemical action, and absence of the property of absorbing gases, which is possessed more or less by all forms of amorphous carbon.   Natural graphites of the high degree of purity required for delicate chemical and electrical processes are so expensive that in most cases the cost is prohibitive.   The inception of the artificial graphite industry is due to the efforts and experiments of Mr. Edward G. Acheson, who during 1897 manufactured more than 160,000 pounds of this product.   In 1901 the output in the United States reached 2,500,000 pounds.   At first the operations were confined to the graphitization of carbon electrodes, but since 1899 very large quantities of artificial graphite have been made, to be utilized for purposes for which natural graphite was formerly used.   In graphitizing electrodes the ordinary electrode, which is composed of a mixture of petroleum, coke, pitch, and a carbide-forming material (silica or iron oxide), is subjected to the intense heat of an electric-arc furnace.   The

so-called artificial graphite is produced by subjecting anthracite coal, coke, or charcoal, together with a small proportion of some oxide or sulphate, to the intense heat of an electric-arc furnace; the impurities are eliminated, the ash being reduced in some cases to as low as five tenths of 1 per cent.

The so-called artificial graphite, which is in the form of grains or powders, is used chiefly in the manufacture of paint, dry batteries, and commutator brushes, although a considerable quantity is used in the manufacture of lubricants for high grade work, in electroplating, and in certain chemical processes which require a carbon of exceptional purity. Experiments have been made with this material as a coating for the grains of high explosives, to prevent the generation of the static charge of electricity, the spark from which is supposed to cause the spontaneous ignition of the powder.

Graphitized electrodes possess special qualities which render them valuable in electrolytic processess for the production of caustic soda and of chlorine and metals in chloride solution, and in electro-metallurgical processes, such as the production of calcium chloride, the electric smelting of copper and iron ores, and the manufacture of various iron alloys.

In spite of the development of artificial graphite, however, in recent years there has been a large increase in the demand for natural graphite, due to the growth of the iron and steel industries, the largely increased use of copper and its alloys; the development of electrical machinery, which calls for graphitized products; and the increased need for special lubricants to be used at comparatively high temperatures.

Graphite is used for making refractory crucibles, stove polish, foundry facings, paint, and lead pencils; as a lubricant; and in powder glazing, electrotyping, steam packing, etc.

For the making of crucibles crystalline graphite is required; the fibrous or laminated variety is used, because its superior binding qualities add to the strength of the crucible. The ordinary mixture consists of 50 per cent of graphite, from 35 to 45 per cent of air dried clay, and from 5 to 15 per cent of sand. The graphite is ground to a fineness of from 40 mesh to 100 mesh size, according to the special use to which the crucible is to be put; if coarse it will give a porous cruci-

ble, while if too fine it will be apt to crack when heated, because of its great density. The clay is selected, not on account of its refractoriness, but because of its plasticity. The sand is free from fluxing impurities, such as iron oxide, lime, magnesia, etc., and is sifted through a 40 mesh screen.

In combining the constituents, the clay is made into a thin paste with water, and the graphite and sand are thoroughly mixed in by repeated treatments in an ordinary pug mill. The mass is kept moist for several weeks, in order to insure the expulsion of any air bubbles which may have been formed in the mixing. This stage of the work is called tempering. A portion of the tempered mixture of the proper weight for a crucible of the desired size is molded into shape on an ordinary potter's wheel. This method is superior to machine molding, because the rotary motion and external pressure cause the flakes of graphite to become arranged nearly parallel to the sides of the molded shape, thus binding the mass together more strongly. The freshly molded crucibles are inclosed for several hours in a close fitting sectional mold of plaster, which absorbs a portion of the moisture; they are then dried for a week or ten days at a temperature of from 70° to 80° F., and finally are fired for several days in a common pottery kiln. The use for graphite crucibles of a fusible clay of great plasticity instead of one of high refractoriness is based upon the fact that for the combination of two substances by fusion mechanical contact is absolutely essential, so that, whether the clay be refractory or not, the presence of an inert material between the particles of clay and sand prevents fusion. Furthermore, as soon as the crucible is placed in the kiln the graphite on the outer surface is burned away by the oxidizing gases, permitting contact between the particles of clay and sand; these, reacting upon each other, fuse and form on the outside of the crucible a glaze which protects from oxidation the graphite flakes beneath the surface.

The quantity of the mineral used for making lead pencils is comparatively small, but the quality must be of the best. For use as a lubricant a high grade of the crystalline product is essential. But material of an inferior grade is employed in

the manufacture of stove polish, of foundry facings, and of graphite paint, which is used to protect ironwork (as in smoke-stacks, iron roofs, elevated steel structures, etc.). While crystalline graphite is used to some extent, its special proper-ties are not absolutely required, and hence the amorphous variety, both natural and artificial, is largely employed for these purposes.

CLAY.

BY JEFFERSON MIDDLETON.

[Jefferson Middleton, statistician; is the recognized authority on clay and the methods of its extraction and manufacture; for the past fifteen years he has been the expert in this line for the United States geological survey, and has written the government reports on the industry; also is author of many articles for reviews and technical periodicals.]

Popularly, clay is an earthy substance which, if mixed with water and molded, will retain its shape after drying, and which upon subjection to high temperature loses its plasticity and becomes hard and brittle.

Technically, pure clay or kaolinite, which is the basis of all clay, is a hydrated silicate of aluminum, expressed by the formula $Al_2O_32SiO_2$, $2H O$. All clay in its natural state contains more or less impurities, the kind and quantity of which determine its character; from purest varieties, called kaolin, clays range through all stages of impurity down to a point where the material contains so little kaolinite that it can not be classified as clay at all.

Clay is ordinarily classified as kaolin, ball clay, fire clay, vitrified ware clay, and brick clay; there are also slip clay, and paper clay. Fire clay includes clays used for stoneware and for terra cotta, which are reported separately by the geological survey. Vitrified ware clay includes the pipe clay, reported by the survey.

In the following description of the physical and chemical properties of the several kinds of clay, the chemical analysis has been supplemented, wherever possible, by what is called the rational analysis. The ordinary quantitative chemical analysis treats clay as a mixture of oxides, although the elements may be present in entirely different combinations, such as silicates, carbonates or hydrates, sulphates, etc. The nature of these combinations is of importance. For example, silica in the form of quartz, which is infusible, will decrease the shrinkage and up to certain temperatures increase the

refractoriness; but if present as a component of feldspar, it serves the purpose of a flux and somewhat increases the plasticity. The advantage of the rational analysis is that it resolves the clay into its mineral components, affording an insight into the physical properties—as fusibility, refractoriness—of the material. This is frequently a matter of far greater importance than the chemical composition; for instance, two clays of the same rational composition will behave much alike if burned under the same conditions, even though they may differ in chemical composition.

Kaolin is a white burning, nonplastic, highly refractory residual clay used in the manufacture of china and other white wares; it must be practically free from iron, as a very small quantity would cause the ware to become discolored in burning. The chief producing states are Pennsylvania, Delaware, North Carolina, and South Carolina.

Ball clay is a white burning, plastic, sedimentary clay, used with kaolin to afford plasticity to the body in the manufacture of white ware, and often incorrectly called kaolin. The distinguishing characteristic of this clay is its plasticity. The chief producers of ball clay are Florida, New Jersey, and Kentucky.

The term fire clay is a rather broad one, embracing not only the high grade clays used for the manufacture of refractory material of all kinds, but also the more or less impure varieties used for stoneware, terra cotta, and yellow and Rockingham ware. Glasshouse supplies, which must be highly refractory, are made from an especially high grade of this clay. Fire clay is subdivided into flint, or nonplastic, and plastic clay. The mining of fire clay for sale is most extensively carried on in New Jersey, Missouri, Pennsylvania, and Ohio.

Clays for vitrified wares, such as sewer pipe, electric conduits, and vitrified paving brick, are those in which the proportion of fluxing impurities is sufficient to allow the clay to vitrify at a moderately low temperature, but not to cause the ware to become soft under the pressure of a column of some height and considerable weight.

Brick clays are divided into those used for common and

for pressed and ornamental brick. Red earthenware, such as flowerpots, is also made of brick clay. Clays suitable for the manufacture of common brick are located in every state and almost every county in the union. Of all clays these are usually the most impure, often containing a rather high percentage of lime. Lime in a finely divided state is not harmful; but in the form of limestone pebbles it is very injurious to the finished product, as the process of burning converts these pebbles into quicklime, which is apt to slack, thus breaking the brick, upon being exposed to the atmosphere. This difficulty is sometimes overcome by passing the clay through a pulverizer, which crushes the pebbles, or by screening it to remove them.

Pressed brick and ornamental brick require a higher grade of clay, the buff varieties being made sometimes from a refractory or semi-refractory clay. The buff color in refractory clay is due to the low percentage of iron; in other clays, notably the Milwaukee clay, from which is made, probably, the best known buff or cream brick, it is due to a large percentage of lime, which enters into chemical combination with the iron, thus neutralizing its coloring effect.

Slip clay is used in glazing low grade products such as earthenware and stoneware. It must fuse at a low temperature and produce a glaze of even color. The clay generally used for this purpose is mined near Albany, N. Y., and hence is known as Albany slip. It produces a dark brown glaze, and is shipped to almost every state in the union.

Paper clay is used, as its name indicates, in the manufacture of paper. As clay used for this purpose is not molded or fired, plasticity, fusibility, and vitrifying qualities need not be considered; hence any pure white, smooth, gritless clay can be used. Where the clay is suitable in color, but gritty, the grit is sometimes washed out. Paper clays are mined in Delaware, Georgia, Maryland, Pennsylvania, and Wisconsin.

There are several methods of mining clay, but only two are generally followed, viz., open pit and underground mining. Open pit mining is conducted in several ways—with pick and shovel, with a scraper, or by falling the clay, that is,

by undermining it and letting it fall. Sometimes explosives are used for the last named purpose.

In underground clay mining the methods of working are the same as those usually followed in coal mining, namely, by shaft or tunnel, with drifts, slopes, and chambers; there are, however, comparatively few deep mines in the clay industry, except where the clay is mined in connection with coal. Kaolin is sometimes mined by sinking through the vein a round shaft, the sides of which are timbered.

The commoner grades of clay are generally sold as mined, because to prepare them for the market in any way would add so greatly to their cost as to make them unprofitable. Even the common clays, however, are sometimes screened or ground to get rid of limestone pebbles or other small stones; screening removes them mechanically, while grinding overcomes their bad effects through comminution. In this country the common clays are not washed. The kaolins and ball clays are, however, sometimes washed at the mines, but they are again washed or prepared at the pottery before being manufactured into white ware. Another method of separating the clay from its undesirable impurities is by fans. This method can only be employed where the impurities are in the form of coarse particles or grains of sand, and consists in first grinding the clay to a very fine powder, after which it is carried to a flue through which a strong current of air is forced; this immediately carries the finer particles to the end of the flue where they are dropped into a bin. The coarser particles are dropped into the flue and carried back to the pulverizer to be ground over again. In the manufacture of pottery, and also of brick by the dry press process, the clay is cured, or weathered, often for months, before being used.

Clay is used most extensively in the manufacture of common building brick; next in importance, as measured by the quantity of material consumed, is front or pressed brick, with its almost limitless variety in color and shape. Then there are vitrified brick, with a large and growing field of usefulness, and fire brick, the shape and utility of which are almost without limit, stove lining being an important subdivision. Other important products are drain tile, sewer pipe, ornamental ter-

ra cotta, fireproofing, roofing tile, flooring tile, and encaustic tile.

In addition there are assayers' supplies, boiler and locomotive tile and tank blocks, building blocks, burnt clay ballast, chemical brick, patent chimney brick, chimney pipes and tops, clay furnaces and retorts, conduits for underground wires, crucibles, cupola bricks, fence posts and fence post stubs, flue linings, frost proof cellar brick, gas logs and settings, glasshouse furnace blocks, grave markers, muffles, porous cups, runner brick, sidewalk tile, souvenirs, stone pumps, terra cotta vases, tile mantels, wall coping, washboards, and well brick and tile.

In addition to the well known pottery products of clay, such as red earthenware, stoneware, yellow and Rockingham ware, and the various grades of white ware from C.C. ware to china, the following wares also are made of clay: Acid proof tanks, art and chemical pottery, bath tubs, caster wheels, electrical supplies, Faience glass pots, insulators, jardinieres, lavatories, pins, stilts and spurs for potters' use, porcelain hardware trimmings, shuttle eyes and thread guides, **pump stands, wash tubs.**

CRUDE MINERAL PIGMENTS.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York city in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

Pigments are substances, both natural and artificial, which are usually insoluble in water, oils, and other neutral solvents, and are used to impart color to a body either by surface adhesion or by direct admixture with its substance. Generally there is no chemical combination between the pigment and the body it covers. When mixed with a drying oil, or with water containing oil or size, the pigments form the basis of paint which is used for decorative or protective purposes.

The natural pigments, the only ones with which this report is concerned, are among the most important but are fewer in number than those prepared artificially by chemical precipitation or other processes. According to Thorp the chief pigments are classified as follows:

Whites: White lead, lead sulphate, lead oxy chloride, zinc white, zinc sulphide, barytes, gypsum, and whiting. *Blues:* Ultramarine, Prussian blues, smalt, cobalt blues, copper blues, and indigo. *Violet:* Ultramarine. *Greens:* Ultramarine, Brunswick green, chrome green, Guignet's green, copper greens, and copper and arsenic greens. *Yellows:* Chrome yellow, yellow ocher, cadmium yellow, orpiment, litharge, gamboge, and Indian yellow. *Orange:* Orange mineral, chrome orange, and antimony orange. *Reds:* Red lead, chrome red, red ocher, Venetian red, vermilion, realgar, antimony red, and carmine. *Browns:* Umbers, Vandyke

brown, and sepia. *Blacks:* Lampblack, ivory black, bone-black, and graphite.

The iron oxide pigments are used to make dark red or brown paints, being known in the trade as natural reds. They are classed as natural and artificial, the former (metallic paints and mortar color) being chiefly made from brown iron ore and ferruginous shales, and the latter (Venetian red, Tuscan red, and Indian red) from calcining copperas or copper residues in a furnace yielding ferric oxide (Fe_2O_3) in a state of very fine division.

Although the occurrence of iron ores in the United States is widespread, and enormous deposits exist at many places, there are very few localities in which the material is of suitable physical and chemical composition for manufacture into metallic paint.

The ores reported for use in the manufacture of metallic paint and mineral paint were mined in Anne Arundel and Baltimore counties, Md.; Carbon county, Pa.; James county, Tenn.; Rutland county, Vt.; Bedford county, Va.; and Dodge county, Wis. The mortar colors were all reported from Northampton county, Pa. Other iron pigments reported were mined in Cattaraugus county, N. Y., and Carbon and Wyoming counties, Pa. The Venetian red reported was all mined in Anne Arundel county, Maryland.

The iron oxide paints are highly esteemed for some purposes on account of their freedom from poisonous ingredients which are found in some mineral paints, and because they resist to a marked degree the effects of light, heat, and moisture, a quality which renders them of great value for outside or exposed work. Ochers in addition resist the destructive action of salt air, and are therefore of special value in localities at or near the seacoast.

A certain proportion of metallic paint is used as a coloring matter in mortar making, and appears in some classifications under the title mortar colors.

The mining and preparation of the crude ore for the market are very simple processes. The ore, generally obtained by open cut or quarrying methods, is disintegrated by exposure to the atmosphere, carried to a mill, roughly crushed,

dried, pulverized, and passed over a screen of bolting cloth or through some type of pneumatic separator, from which the final product is classified and packed for shipment. At times the ground ore is levigated and the settled products dried and packed for shipment.

The name ocher is applied to clays and other earthy bases containing in their natural state sufficient ferrous or ferric oxide or hydroxides to impart to the mass a bright red or yellowish red tint. The color varies from a golden yellow to a dark red, occasionally possessing various tints of blue and green.

The ochers reported were mined in Clay county, Ark.; Calaveras and Stanislaus counties, Cal.; Bartow and Richmond counties, Ga.; Berks, Lehigh, Luzerne, and Northampton counties, Pa.; Rutland county, Vt.; and Page county, Va. The sienna reported was mined in Washington county, N. Y.; and the umber in Lawrence county, Pennsylvania.

The ochers have been used as paints from a very early date, the oldest applications positively recognized having been made in Italy, though it is believed that some varieties were in use still earlier by the Egyptians and Greeks. In modern times the ochers were first mined and prepared in Italy, and the siennas and umbers derive their names from the Italian towns in which they were manufactured into pigments.

Ochers are classified in many ways, according to the locality of occurrence, the composition, and the special shade of color. Practically they may be grouped into yellow, red, and brown. Yellow ocher is that which is colored by a ferric hydroxide. Red ocher owes its tint to ferric oxide, and it is therefore evident that red ocher may be prepared artificially by expelling the water from yellow ocher by calcining in a furnace or kiln. Brown ocher is red ocher modified by the presence of black manganese dioxide, which in various proportions yields a large range of brown colors, notably sienna brown, umber, Vandyke brown, and manganese brown.

The variation of ocher in shade and in quality depends chiefly, but not entirely, upon the proportion of iron oxide

present as well as the quantity of water combined with the iron oxide. A red ocher, improperly called iron minum, very rich in iron oxide, is made by calcining and pulverizing limonite that is free from clay.

There are few pigments more free from adulteration than the ochers, for the reason that any filler that can be used advantageously is more costly than the ocher itself. Sometimes a little chrome yellow is added in order to improve the tone of a poor colored ocher, but the presence of this adulterant is very easily detected. Oxford ochers are the brightest and best of the mineral pigments of this class. They are obtained from Oxford, England. The German pigments are often called ochers, although improperly so, for the reason that they are ligneous earths and not ferruginous clays. The manufactured product varies greatly in quality and value, and some of the grades pass insensibly into umber or sienna.

Umber and sienna in reality are varieties of ocher which have been isolated on account of the brown color which is imparted to the natural clay material by the addition of iron and manganese oxides; raw umber is of a brown color, while burnt umber is of a somewhat richer and redder hue. Raw sienna is of a brownish yellow shade which affords a rich russet brown when burned. Intermediate shades of color are obtained by mixing natural products with various properties of iron and manganese oxides, and sometimes by mixing both raw and calcined materials together.

A few tons each of slate, shale, and soapstone (the last named being a variety of the mineral talc) are annually ground in the United States to produce a gray colored pigment used chiefly as a filler for mineral paints, especially those of the variety called fire retarding.

Gypsum, known also as terra alba and mineral white, is a natural hydrated calcium sulphate ($CaSO_4$, $2H_2O$). It is used to a minor extent as a pigment for printing wall paper. The method of making this pigment consists in grinding the mineral and treating it with acid in order to remove any tint or color resulting from the presence of

iron oxide. The gypsum, or white mineral reported in 1902 was mined in Cape Girardeau county, Missouri.

In addition to the natural iron oxide pigments, made by a simple washing and grinding of pure crude ores, there are two very important artificial iron oxide pigments made by roasting the residuum obtained from making copperas, or green vitriol ($FeSO_4,7H_2O$). One is Venetian red, composed almost wholly of artificial iron sesquioxide, and the other Indian red, which is comprised of about 40 per cent of iron sesquioxide, the balance being mainly calcium sulphate, made by adding a certain proportion of lime during or before the roasting.

There are two methods of manufacturing these artificial reds, the dry and the wet. In the former method which is the cheaper for the low grades of oxides, the impure copperas is roasted in a furnace with lime or similar material, in order to neutralize the acid in the sulphate until the desired strength and color of the product are obtained. Occasionally copperas alone is roasted until the acid constituent has been completely expelled, leaving the residuum in the form of pure iron sesquioxide; a filler (whiting or gypsum) is then added in proportions to yield the desired grade of Venetian red, some containing as little as 10 per cent of iron oxide or coloring power.

The wet method is cheaper for the manufacture of the general grades of Venetian red, but yields a less uniform product than the dry method. In principle, the waste liquor from the cleansing or pickling process in preparing iron wire or plates for galvanizing by immersion in weak sulphuric acid is treated direct by the addition of milk of lime, sodium carbonate or similar reagents, which precipitates the iron as a hydrate or carbonate to the bottom of the tank. This precipitate is subsequently separated from the liquor by filtration through a press, the dried cakes remaining therein being subsequently roasted in furnaces, cooled, and packed for the market without grinding. The product made in this manner is not uniform in quality, and has but a limited use.

Hematite ore is sometimes ground and sold as Venetian

red. The natural products, however, are inferior to the artificial and do not command as high a price.

Formerly the iron oxide pigments made in the United States did not contain more than 50 per cent of iron oxide, the higher grades being imported. Recently, however, the use of a crucible furnace of special design, which gives good control of the heat and of the oxidation, has raised the grade of the product to practically 100 per cent of iron oxide.

Improvements have also been made in the wet process, chiefly in the substitution of mechanical appliances for hand labor, which has lessened the cost of production and given a more uniform product.

Among other minerals used in part in the manufacture of paints are barytes, asbestos, graphite and asphaltum.

The mineral is generally prepared as follows: The crude ore is hand sorted and the limestone rock and other foreign materials removed; the select ore is then crushed and boiled in dilute sulphuric acid in order to remove any remaining impurities, chiefly iron oxide, which may impart a tint or color to the product. The material is then thoroughly washed after boiling to free it from acid or soluble salts and is finely ground and put on the market in four varieties: No.1, No. 2, No. 3, and floated or water sorted.

Barium sulphate, known as blanc fixe, which has been precipitated artificially as a by-product in some chemical industries, is used to a considerable extent as a filler and pigment. It has more body and greater capacity and covering power than the native mineral barite, for the reason that it is amorphous, while barite is crystalline.

The chief use of barite is as a pigment which is usually mixed with white lead. In the United States it is regarded as an adulterant which depreciates the value of the paint, but in Europe it is considered a valuable addition, and in many cases a pigment composed of a mixture of barite and white lead is considered more serviceable than white lead alone, for the reason that, owing to the insolubility of barite in acids, it imparts elasticity to the mixture, gives a greater body to the paint, and resists the influence of the weather better than white lead alone.

Asbestos can hardly be classed as pigment, although when used as a filler its white color lightens the color of the material to which it is added. The chief use of asbestos in paint manufacture is to yield a so called noninflammable or fireproof paint. The fibrous varieties of talc are also used for this purpose. Only a small proportion of the total production of asbestos in the United States is utilized in paint manufacture.

Both the natural mineral and the artifical product made in the electric furnace are used as a black pigment and in pencils, crayons, and in stove polish. The color of the pigment is a dull black and permanent, and on account of its resistance to the action of the atmosphere, as well as that of ordinary chemicals, it is of great value as the basis of a protective paint for coating oxidizable metals, chiefly iron and steel.

The purer grades of asphaltum are largely used as a basis for the manufacture of a black varnish, and as a protective paint for the interior of chlorine stills, bleaching powder chambers, acid tanks, and like apparatus. Asphaltum is not acted upon by ordinary chemicals, and for this reason it is invaluable for protecting structures of iron, steel, and even wood, which would be rapidly destroyed by acid fumes unless coated with some inert material.

Whiting, or Paris white, is composed of calcium carbonate($CaCO_3$). Calcium carbonate occurs quite extensively in nature, either in the crystalline form, as the well known mineral calcite, or calc spar, or in the compact form, such as marble and limestone, or as the soft compact variety known as chalk. It is produced artifically as a by-product of many chemical operations. The whiting used in commerce is generally prepared by grinding and levigating pure chalk, large deposits of which occur, notably in England and France. The chief use of whiting as a pigment is to modify the shade of other pigments. It is also largely used as a basis for whitewash, and when mixed with from 15 to 18 per cent of linseed oil it forms putty.

PRECIOUS STONES.
BY GEORGE F. KUNZ.

[George F. Kunz, expert in precious stones; born New York, September 29, 1856; since 1883 has been gem expert of the United States geological survey; was in charge of the department of mines at the Paris Exposition of 1889, and at the World's Columbian Exposition at Chicago in 1893; has been vice president of the American Institute of Mining Engineers; is now gem expert for Tiffany & Co. Author of Gems and Precious Stones of North America, and of about 150 articles on gems and minerals for magazines and reviews.]

Precious stones derive their value chiefly from their rarity. Other qualities that influence their value are beauty of color, hardness, and the caprice of fashion. Under this classification a distinction could be made between precious and semiprecious stones, but it is not observed in this discussion. Precious stones include the diamond, the sapphire, the ruby, and the emerald; semiprecious stones include a wide variety of other gem minerals. The opal and the pearl are sometimes classed as precious stones, although the latter is not strictly a mineral product. In ordinary speech the precious or semiprecious stone signifies a gem cut or polished for ornamental purposes. In mineralogy the term is used to designate a class of minerals of sufficient hardness to scratch quartz, which are without metallic luster, although generally brilliant and beautiful. In archaeology the term is restricted to engraved stones, such as intaglios and cameos. A jewel is a gem that has been mounted.

The diamond, the hardest of known substances, is pure carbon, which crystallizes in the isometric system, generally in an octahedral form. Its specific gravity is 3.525. It occurs in a great variety of colors, ranging through all the shades of the spectrum, occurring most frequently as white, yellow, or brown, and rarely as red, rose red, blue, or green. By far the greatest number of diamonds come from South Africa, but they are found also in Brazil, India, Borneo, and occasionally in North America.

In the United States diamonds have been found at various points, but they have been few in number, and mostly of small size. Their occasional occurrence in California and east of the southern Alleghanies has been known for fifty years. Since

1890 a few others have been found in these regions, and some in the northwestern states, varying from one third of a carat to 21 carats in weight.

The northwestern diamonds are very interesting as being contained in the deposits of the glacial drift, scattered along an irregular line of some 600 miles, from Wisconsin to the vicinity of Cincinnati, Ohio. All the material distributed by this ancient glacial action has been brought down from the north, and therefore the source of these diamonds is somewhere in the unexplored regions of Canada and not in the United States. Geologists recognize two distinct drift deposits in the western states, called the older or Illinoian drift, and the later or Wisconsin drift. Some of the diamonds found in Indiana and in Wisconsin are referred to one of these drifts and some to the other, though most of them belong to the later. The whole number of diamonds actually known from these glacial deposits amount to about 25, over half of which are from Wisconsin and one third from Indiana.

The localities of discovery during the period since 1890 are as follows:

Alabama.—Shelby county, one of $4\frac{1}{2}$ carats. Lee county, one of 3 carats.

California.—A number of localities, chiefly in the central portion of the state, in connection with the hydraulic gold washings of Amador, Butte, Eldorado, and Nevada counties. A single diamond is reported from Tulare county, and a number of very small ones in the gold sands of streams in Del Norte and Trinity counties. No large stones have been found in California, and nowhere are they abundant enough to lead to any mining for them. Nevertheless some handsome ones have been casually obtained in the central counties above named, chiefly in the ancient gold-bearing gravels overlaid by lava flows, and fragments of diamonds crushed by the stamp mills are not uncommon in the flumes and sluices. Most of the stones found within recent years have come from the vicinity of Placerville, Eldorado county.

Indiana.—Brown county, five—one of 2 carats, others very small. Morgan county, three—one of $3\frac{3}{4}$ carats, others very small.

Kentucky.—Cabin Fork creek, Russell county, one.

Michigan.—Dowagiac, Cass county, one of $10\frac{7}{8}$ carats.

Ohio.—Milford, Clermont county, one of 6 carats.

Tennessee.—Koko creek, Tellico river, Monroe county, several reported. Union Crossroads, Roane county, one of 3 carats. Luttrell, Union county, one of $1\frac{13}{16}$ carats.

Wisconsin.—Plum creek, Rock Elm township, Pierce county, several very small stones. Oregon, Dane county, one of $3\frac{13}{16}$ carats. Kohlsville, Washington county, one of 21 carats. Saukville, Ozaukee county, one of $6\frac{3}{8}$ carats. Eagle, Waukesha county, one of $15\frac{13}{32}$ carats. Burlington, Racine county, one of $2\frac{1}{16}$ carats.

The whole subject of the Indiana occurrence is fully described by the state geologist, Prof. W. S. Blatchley, in his annual report for 1902. The geological features of the region are first treated with special reference to the distribution of the drift deposits in central Indiana. These have been known since 1850 to contain gold, and a large amount of local prospecting and panning has been carried on along the streams for years. The gold is found associated with magnetic iron sand, menaccanite, and other heavy minerals. It is in these auriferous sands that diamonds have been found at intervals for some twenty five years, but especially of late. Some of the diamonds belong certainly in the second, or later, drift, like most of those in Wisconsin; others found south of that line but within the margin of the older drift belong, perhaps, to the older deposits instead of having been washed out from the later beds and carried south by streams, as formerly supposed. The terms earlier and later are now frequently replaced by Illinoian and Wisconsin, and designate the two glacial drifts, but these terms may be misconceived as to their geographical signification and hence require explanation. The center of ice movement in the glacial era was determined some years ago by Canadian geologists as having traveled or shifted toward the east from the west. Of the two ice invasions that spread over the northern United States, the earlier is called by some geologists the Illinoian, as having covered a large part of that state not reached by the later one; while the name Wisconsin is applied to the later by Prof. T. C. Chamberlin, because it extended

westward to a portion of that state not covered by the earlier, and formed there what he terms the Wisconsin boundary, although its source was far east of the earlier drift, and it forms the main deposits of the eastern states.

Professor Blatchley's list comprises eight diamonds that he himself has seen, and seven more of which he has credible information. The earliest published mention of the occurrence of diamonds in Indiana was made by the late Prof. E. T. Cox, state geologist, in his annual report for 1878, page 116, although the well known artist Mr. Daniel Beard, of New York, owns a fine diamond of about 2 carats found in Indiana before that year. Professor Cox mentions several diamonds, of which this may be one, as found in the drift of Brown and Morgan counties, and refers to them with interest because of their evident transportation from a far northern source. Of the eight stones seen by Professor Blatchley, four are from the newer and four from the older drift, or at least from the area covered by it south of the margin of the newer.

The sapphire, ruby, oriental topaz, oriental amethyst, and oriental emerald are names given respectively to the transparent blue, red, yellow, purple, and green varieties of corundum, which is nearly pure alumina, A_2lO_3. The colors of these minerals are ascribed to the presence of minute quantities of metallic oxides. Their specific gravity ranges from 3.97 to 4.05, and their hardness is 9. Rubies are found in Burma, Ceylon, and Siam. Sapphire also occurs in these countries, as well as at the Simla pass in the Himalayas and in Australia.

The great hardness of corundum gives it a special value for polishing purposes. Although corundum is found in the crystalline rocks along the Appalachian mountains from Massachusetts to northern Georgia, few gems of any special value have been found, except in the Cowee valley in North Carolina, where true rubies are obtained to some extent, although mining has ceased for a few years past. Other deposits in which these gems are found exist in Montana. Sapphires of the finest quality are now mined in Yogo gulch, and others of much beauty are found at other points in the same state.

Until within a few years, these gems had been found only occasionally in the United States—nearly all of them in North

Carolina—and were principally cut from small transparent portions of the colored corundums that were otherwise more or less opaque. Corundum is mined in that state extensively as an abrasive material, and ruby and sapphire are simply transparent varieties of it. The Montana gems began to attract notice about 1869, and for some years they were collected abundantly from the bars of the upper Missouri east of Helena; these were of varied and often beautiful tints of pink, blue, green, and intervening shades, but rarely of the deep colors in favor for jewelry. The latter, the rich blue sapphires equal to those of India, have since been found at Yogo gulch, in Fergus county, and active work in mining them from the rock has been carried on for several years by the New Mine Sapphire syndicate and the Burke & Sweeney company. Two other important localities in Montana are at Rock creek, in Granite county, and Dry Cottonwood creek, in Deerlodge county, worked by the American Gem Syndicate company. The former of these yields a wonderful variety of colors, often very beautiful, but few that have the deep shades most valued in the gem market. No locality in the world has shown such variety of tints in sapphires—pink, reddish brown, brown, yellow, green, etc., with occasionally a ruby of the paler type of Ceylon. Gems of considerable value have been annually mined at Yogo gulch for several years past. Fine sapphires of the cornflower and velvet blue of the best oriental stones have been obtained, weighing as much as 3 carats, and a few as high as 5 and even 7 carats after cutting. Besides those used for setting, large quantities of small ones from both these localities have found ready sale for watch jewels and bearings; indeed, more have been sold for this purpose than for gems.

True rubies have been found and to some extent mined, in the Cowee valley, Macon county, N. C. Some of them have the rich and peculiar pigeon's blood color of the finest rubies from Burma, but the crystals are small or imperfect, and the yield thus far has been quite limited. The operations were conducted by the American Prospecting and Mining Company.

True emeralds, suitable for cutting and setting, can hardly be said to be found in the United States. It is true that large and very fine crystals of emerald were obtained at Stonypoint,

Alexander county, N. C., in 1877; but these, although valuable and beautiful as specimens, were not clear enough to cut into gems. More recently a locality has been opened at Crabtree, Haywood county, in the same state, where small and handsome emerald crystals, both translucent and opaque, occur thickly in the white feldspar and quartz of a vein of pegmatite (coarse feldspathic granite). This green and white mixture is very pleasing, and as the three minerals have nearly the same degree of hardness, the whole can be cut and polished together, making a novel and beautiful ornamental stone. Pieces are cut en cabochon, i. e., rounded, not faceted, showing sections of the emerald crystals in different directions in the white mass. This material has been introduced into ornamental and minor jewel work under the name of emerald matrix, by the American Gem company.

Beryl is essentially the same mineral as emerald, though of paler shades and much less esteemed. Fine transparent beryls, however, are choice gem stones, and several varieties of them are found in the United States. Among these are emerald beryls, of rich light green shades, aquamarines, faintly tinged with green; golden beryls of a rich yellow; blue beryls, sometimes almost as beautiful as pale sapphires; and rose beryls of light pink color. Some very fine gems have been cut from crystals of these kinds, especially from Topsham, Me., in the quarries of the Trenton Flint and Spar company. Other fine gems come from Connecticut, North Carolina, and Colorado. In North Carolina, near Sprucepine many fine beryls— some of the richest blue color ever found—have been mined by the American Gem company. The finest and largest aquamarine known is from Stoneham, Me. Golden beryls of much beauty have been cut from material mined at Merryall, in Litchfield county, Conn. Green and blue beryls have been found in North Carolina, and aquamarines at Mt. Antero, Colo. The discoveries of fine gem material are, however, not frequent nor in large amount, so that there is no systematic mining or regular production.

Topaz is a fluosilicate of alumina and crystallizes in rhombic prisms with a hardness of 8. The true topaz occurs but sparingly in the United States, although here and there it has

This may prove to be a source of choice gem material, although as yet the amount of it present has not been ascertained.

Tourmaline belongs to the rhombohedral system of crystallization, occurring in prisms, the sides of which are generally striated and channeled. The transparent variety is of a hardness of 7.5, its specific gravity ranges from 3 to 3.25, and in composition it is a very complex silicate of aluminia. Many different colors are found, ranging all the way from a colorless variety through red, green, blue, and brown, to black. These differences in color are chiefly due to the varying amounts of manganese and iron present. The gem is dichroitic; thus when viewed from the side it may be a transparent green, but either opaque or yellow green when viewed endwise of the prism.

Tourmaline was but little known in jewelry ten years ago, although some very beautiful gems had been cut from the transparent red, green and blue crystals obtained at Paris Hill, Me., and at Haddam Neck, Conn. Some mining had been done at these places, and many splendid specimens obtained. But within a few years past, wonderful discoveries of gem tourmaline have been made in southern California, at Pala and Mesa Grande, in San Diego county, and in the San Jacinto mountains in Riverside County. The crystals found at these localities are of great size and beauty, and gems have been cut from them in abundance. A single collection of these crystals has been valued at $10,000. The prevailing colors are pink, salmon and red, all in very rich shades, also fine green and blue, though less frequently in these colors than those found at Mt. Mica and other localities near Paris, Me. Tourmaline is peculiar in that it often presents two or three different and even contrasting colors in the same crystal, which sometimes shade into each other, but often present a sharp line of contact. Advantage has been taken of this feature, which is marked in the California crystals, to produce in jewelry the novelty of parti-colored gems. Beautiful cut stones may now be seen that are half red and half green, or showing other similar contrasts.

There are two mines at Pala, Cal., owned by the Pala Lithia company, one of which yields beautiful specimens of rather small and opaque pink tourmaline crystals, in radiated

groups, in lilac lepidolite (lithia mica), none of which, however, is suitable for gem material. The mine is worked for the lepidolite, as a source of lithia compounds, and specimens find a ready sale to collectors and museums. The other mine, which has only recently been discovered, carries large and splendid crystals of tourmaline of mingled colors, and also a new gem named kunzite, a transparent lilac spodumene.

Reference has been made above to the discovery of the new and interesting gem stone kunzite, at Pala, Cal. This locality is remarkable for its lithia compounds, among which are the colored tourmalines and the spodumene, both of which contain lithia in small amounts, combined with silica, alumina, and other oxides.

The mineral spodumene is usually obtained in large, opaque, whitish crystals, but from time to time small specimens, often richly colored and transparent, are found. The three characteristic varieties of the latter are a clear yellow gem spodumene from Brazil, the green hiddenite or lithia emerald of North Carolina, and small lilac specimens sometimes found in Connecticut. These last are without doubt remnants of large crystals, which must have been very beautiful. Spodumene is particularly subject to alteration, and when found has usually lost all its transparency and beauty of tint.

Large and magnificiant crystals of unaltered spodumene, of rich lilac color, have now been discovered near Pala, San Diego county, Cal., in connection with other lithia minerals. This locality has yielded crystals measuring 10 by 20 by 4 centimeters, perfectly clear, of a rose lilac tint, varying with the spodumene dichroism from a very pale color when looked at across the prism to a rich amethystine hue observed longitudinally. No such spodumene has ever been seen before, and the discovery is of great mineralogical interest. The crystals have been etched by weathering like the hiddenite variety. When cut and mounted parallel to the base, they furnish gems of great beauty, entirely new in jewelry, and make a notable addition to American gem stones.

Californite (vesuvianite) a mineral which promises to be a notable addition to the increasing list of semiprecious or ornamental stones found in the United States, has recently

been discovered in California. This is not a new mineral species, properly, but a compact massive variety of vesuvianite (idocrase). It was first announced in the report of the United States geological survey for 1901, by the writer, as having been found by Dr. A. E. Heighway, on the south fork of Indian creek, 12 miles from Happy Camp and 90 miles from Yreka, in Siskiyou county, Cal. Here a hard and handsome stone, varying in color from olive to almost grass green, and taking a fine polish, outcrops for some 200 feet along a hillside about 100 feet above the creek, and large masses have fallen into the bed of the creek. At first it was supposed to be jade (nephrite), but upon analysis proved to be vesuvianite. The fallen pieces were in some cases as much as 5 feet square and 2 feet thick, of excellent quality for polishing, and of varying shades of light to dark green. The associated rock is precious serpentine.

In the region about Lake Superior occur two or three peculiar little minerals that have attained some value as local gem stones. These, in the order of their importance, are chlorastrolite, thomsonite (properly mesolite), and lintonite; besides one or two other varieties, rarer and of less account. These are all nearly related in composition, being silicates of alumina with varying amounts of lime and oxide of iron. They are all found as rounded nodules, not from wear, however, but natural, as being the filling of small ovate cavities (originally bubble holes) in the trap rocks of the region. As the rocks decompose the harder nodules fall out, and are rolled on the lake beaches or by streams, and are often supposed to be pebbles, but they are not such in reality. They seldom exceed half an inch in diameter, but when polished they make quite pretty stones, and are in considerable demand for local jewelry, as rings, studs, and the like.

Prior to 1889 no precious opal had been found in the United States. At about that time, however, and during the subsequent decade, several occurrences of it were discovered, and mining operations were undertaken at some points with apparent promise of successful yield. But for various reasons no important or continuous production has been developed as yet, although the igneous rocks of Washington, Idaho,

Oregon, California, Nevada, and Utah, undoubtedly contain much handsome opal.

The first important opening was in 1890, near Moscow, Latah county, Idaho, close to the Washington line. Buildings were erected, and a fine postoffice called Gem City was established. Fine opal was present in the trachyte rock,and for a year or two there was considerable production. In 1891 the value of the output was estimated at $5,000. For some time past, however, little has been heard of this formerly promising locality.

Other occurrences were noted at about the same time. One of these was in Morrow county, Ore., where several thousand dollars' worth of specimens were said to have been obtained in 1892, and many were exhibited at the Spokane fair. Another was at Opaline, in Owyhee county, Idaho, and exhibits of these were made in the Idaho section of the Mining building at the Columbian exhibition in 1893. Another occurrence was reported in 1895, near Salmon city, Lemhi county, Idaho, where beautiful opal was found in boulders of trachyte, and finally traced to the ledge whence it had come. Many very handsome pieces were obtained, and the mineral was present in great variety of color and quality, but no definite work seems to have been undertaken.

In 1902, one or more promising occurrences were announced in southern California, in the region of the Mojave desert. One of these is in San Bernardino county, about 25 miles north of Barstow, the junction of the Santa Fe and California Southern railroads. Here opal occurs in veins and pockets in a porphyritic dike about 2 miles in length. Much of it is semiopal, of various colors, some a beautiful amber yellow, and with these occur precious and fire opal. The locality is promising but needs to be explored and developed. In Tulare county, also, are found some beautiful semiopals that might be valuable in ornamental art work. One of these, from near Yokohl, is transparent yellow and amber like; another is from the chrysoprase mine near Visalia. It is translucent green, and has been called chrysoprase opal or chrysopal, by the discoverer,Mr. B. Braverman. The Idaho locality at Panther creek, Lemhi county, before alluded to,

has been rediscovered and described during 1902. Opal of many varieties and colors is abundant here, in a porphyritic dike, traced for a mile and a half, parallel to the creek, and at times as much as 150 feet wide. Much of it is very beautiful, but it is also very brittle, and goes to pieces in extracting it, so that stones of any size are difficult to procure.

There are many minor occurrences that have been noted and many varieties of semiopal that may hereafter yield material of some value in the arts. Gem opals, however, are not yet produced to any extent, or with any regularity in the United States, although there is considerable promise at several points.

Turquoise is a hydrated phosphate of alumina, containing small quantities of copper, iron or manganese. The mineral varies in color from a fine sky blue to many shades of bluish green, and to apple green and dark green, which show no blue whatever. The hardness of the mineral is 6, and its specific gravity is 2.75.

Turquoise was almost unknown in the United States until 1890. A few specimens in collections of minerals attested its existence at some points in Arizona and Nevada, and objects worked by the Indians of the southwest were known to be abundant, but there was no production of it, and all the turquoise used in jewelry came, as it had for centuries past, from the mines in Khorassan, in eastern Persia. Since then a remarkable change has taken place, and the southwestern states and territories are now furnishing the main supply for the world. Turquoise has been discovered at a number of points and in large quantities and of fine quality. It is known to exist in Arizona, New Mexico, Nevada, and southern California, while some localities are reported in Texas and southern Colorado. The main production is in New Mexico, in Santa Fe and Grant counties, and at Turquoise mountain in Arizona. The California localities operated by the Himalaya and the Toltec companies are northeast of Manvel, in San Bernardino county. At almost every point where the mineral is found there are interesting and conspicuous evidences of ancient workings in pre-Columbian times; in many cases these were plainly both extensive and long continued; stone

tools and similar objects are abundant, and at some points remarkable rock carvings are to be seen, especially about the California localities. The Toltec turquoise company has also operated other mines near Manvel, Cal., over the line in Lincoln county, Nevada.

Turquoise is now being regularly mined in New Mexico, at perhaps a dozen places, by the Azure turquoise company, the American turquoise company, the Gem turquoise company, and by Mr. A. C. Young; and in Arizona by six companies, among them the Aztec turquoise company. In 1902 turquoise was discovered in Alabama, on property of the Otero company, near Idaho, Clay county, about 95 miles east of Birmingham, in the region of the Talladega mountains. This mineral sometimes loses or changes its color, and for this reason several of the above named companies engrave a trade mark upon the back of every stone that they sell as a guarantee that the company will replace it with another stone in case of any failure of quality appearing within six months after its sale to the retail purchaser.

Several handsome and interesting minerals, related to or resembling turquoise, have been identified in Utah during the last decade. Some of these have been largely sold as specimens, though as yet they have not been found in sufficient quantity to be mined for use in the arts. They would, however, be beautiful ornamental or semiprecious stones. Two of these minerals are utahite and prosopite.

Utahite, so named by the writer in 1895, was discovered in Cedar valley, in a spur of the Oquirrh mountains, near camp Floyd, Utah, in the previous year, by Mr. Don Maguire. It belongs to the mineral species variscite, but presents a new and peculiar form. Variscite usually occurs in crystals or incrustations; utahite forms compact nodular masses, ranging from the size of a walnut to that of a cocoanut. These occur in slaty layers in a crystalline limestone, and are generally surrounded with a brown ferruginous crust. In color the interior mass is of various shades of bright green, generally a very vivid golden green or light emerald; and the nodules, cut across and polished, have been much admired and sought by collectors. The mineral is not very abundant at the locality, and can only

be removed from the rock with care by the hands. Pieces could be easily cut for small objects, and would be extremely handsome for such uses, owing to the brilliant and delicate coloring. It has been used to some extent for ring stones, cuff buttons, seal rings, and other purposes as jewelry with considerable success.

Prosopite at first was supposed to be identical with utahite, but an analysis made by Mr. W. J. Hillebrand proved it to be a fluoride of alumina, known already as a rare species of mineral from Saxony, Germany, and from Pikes Peak, Colo., where it occurs, but without the rich blue green color of that found in Utah. Here it was obtained by Mr. Josiah Beck in 1895 in the Dugway mining district, in Tooele county, in a region of low and desert hills. The mineral was not fully identified until 1899, when the analysis was made and the result published. The prosopite is a beautiful stone, but whether it exists in sufficient amount to be of practical use has not yet been determined.

There is a small but fairly constant sale in the coal region of eastern Pennsylvania of articles of ornament carved from anthracite coal, such as inkstands, paper weights, etc. These are usually made partly polished and partly rough, so as to show a contrast between the two different kinds of black surfaces. They are sold almost entirely as local souvenirs to persons visiting that part of the country. The sale of such articles has been estimated for some years past at a total varying from $1,000 to $2,000.

Catlinite, or pipestone, celebrated in Indian history and immortalized by Longfellow in Hiawatha, is used to some extent for making ornaments and souvenirs that are sold to visitors in the region of its occurrence—Pipestone county, in southwestern Minnesota. It is not really a definite mineral species, but essentially an indurated red clay.

The old and celebrated Shawneetown region in southern Illinois has lately been yielding fluorite of remarkable beauty. In a lot of specimens recently sent to the writer for examination were cleavage pieces of much beauty from several of these localities, notably the Empire mines and Cave-in-Rock. From the former were large cleavages of rich reddish purple,

and of the peculiar sea blue of that region; in one case the general color was of the latter kind, clouded at points with the former—like the tint of a blue Alabashka topaz with included clouds of Uralian amethyst. Both the purple and the sea blue varieties at times pass into almost colorless fluor. That received from Cave-in-Rock presents an octahedral cleavage, perfectly transparent and of amber yellow. A cubical crystal received from Rosiclare was pale bluish, becoming nearly colorless.

Rock crystal is a variety of transparent colorless quartz, composed of nearly pure silica. While it is not rare as a mineral, yet it is seldom found in masses of large size. When so found, however, it is valuable for use in the ornamental arts. One or two localities in the Alps, that have been known and worked from Roman times, though very difficult and perilous of access, have furnished material for all the objects in European palaces and museums which have been carved from this substance. In Japan, too, large crystals were formerly obtained, from which were made the polished balls so much prized by the natives, and afterwards by foreigners, who have now almost drained the country of them by purchase. The main supply in recent years has been derived from Madagascar and Brazil.

Within the last decade very fine rock crystal masses have been obtained in the United States, especially in California. An important discovery was made in 1891-92 by Mr. James Blackiston, near Placerville, Eldorado county.

The most remarkable discovery of quartz in California, however, was made in 1897, in Calaveras county, at the old Green Mountain mine, in Chile gulch, near Mokelumne Hill. Here, in one of the ancient river channels filled with auriferous gravel and covered by an overflow of lava—a formation characteristic of that region of the state—was found a quantity of enormous quartz crystals, imbedded in the old gravel.

In Oregon, large transparent masses have been found near Bay City, but no particulars of their occurrence are given.

Some fine rock crystal occurs in North Carolina, in Chestnut hill township, Ashe county, on a spur of Phoenix mountain, near Long Shoal creek. Here, at two or three spots not

far apart, were found pieces up to 50 pounds in weight, and two very large crystals, of 188 and 285 pounds, respectively, Another find in North Carolina was reported in 1896, from Elkin, in Surry county, by Mr. R. M. Chatham, who described crystals up to 40 pounds in weight. Some large crystals are also known to have been found in South Carolina, and it is probable that much rock crystal adapted for use in the arts exists in the mountain regions of the South.

Colorado has furnished some fine material, especially that from Mt. Antero, Chaffee county. A polished ball, six inches in diameter from the summit of this mountain was exhibited at the Columbian exposition.

A find of considerable quantity was reported in 1896, at Cheyenne pass, Wyoming, about 18 miles west of Cheyenne city, but no development at that point appears to have been undertaken.

The quartz crystals of Hot Springs, Ark., have been known for many years and furnish a constant source of business to the farmers of the surrounding country, who collect them and bring them in by the wagon load to sell to local dealers and to tourists. These crystals are not large enough to yield art material, but they are beautiful as specimens, either as single crystals or more frequently in groups. It is estimated that in one year no less than 15,000 pounds were gathered in Montgomery, Saline, and Garland counties.

Among the colored varieties, besides amethyst, of crystalline quartz suitable for use as precious or semiprecious stones, two are important—smoky quartz and rose quartz. Both are found at various points in the United States and have been mined more or less during the past ten years, although there is no large or continuous supply.

The most noted place in which smoky quartz occurs is at and near Pikes Peak, Colorado, where it is abundant in fine crystals, in a coarse granite, associated with the beautiful crystals of green feldspar (amazon stone), for which that locality is famous. It is found also at Mt. Antero, in Colorado, where the smoky quartz obtained in 1891 yielded one of the finest faceted stones in the world, measuring $3\frac{1}{2}$ inches in length. Much of the material from Pikes Peak is sent abroad

for cutting, and returned to be sold at Denver and Colorado Springs, Colo., at Hot Springs, Ark., and other interior resorts, as jewelry to tourists. The annual sales amount to about $10,000, three fourths of which is for cut stones and one fourth for specimens.

Large crystals, up to 4 or 5 inches in diameter, have been collected at Brandy creek, in Lemhi county, Idaho. They have been found, too, at Three Mile gulch, near Helena, Mont., and a gigantic crystal, nearly two feet long and weighing $93\frac{1}{2}$ pounds, was found in 1900, on Clear creek, Jefferson county, Mont., by Mr. E. P. Chisolm. Crystals have also been reported at points in South Dakota. A considerable quantity occurs in connection with the colored tourmalines in Southern California, both at the San Jacinto mine in Riverside county and those at Mesa Grande in San Diego county.

In the east very fine smoky quartz has been found in Maine and in North Carolina, as well as at some other points. The specimens from Maine are particularly beautiful. Crystals of 40 pounds in weight were reported in 1896, by Mr. R. M. Chatham, from a locality near Elkin, in Surry county, N. C., and it was already well known in the neighboring counties of Alexander, Burke, and Iredell.

The delicate pink variety of quartz known as rose quartz has long been obtained at several points in New England, especially at Albany, Stow, and Paris, in Maine; at Southbury, in Connecticut; also at Bedford, in Westchester county, N. Y. Though a beautiful material, it had been little used in the arts or as a gem until quite recently, when it was tried with some success. In general, and particularly in the case of the specimens from the localities in Maine, the tint varies greatly from an almost colorless variety, sometimes opalescent, to pale pink, salmon, and deep rose. When cut into double cabochons, or balls, it sometimes shows the asteria effect, like a star sapphire. Very fine, rich colored pieces, partly opalescent and in size up to 4 or 5 inches in diameter, have been obtained at Round mountain, near Albany, Me. Rose quartz occurs also at Acworth, N. H., in the celebrated beryl locality, and a large block of this material, some 5 feet square by half

that thickness, has been set up as a monument in Franklin, New Hampshire.

By far the most extensive occurrence, however, is in the Black Hills of South Dakota. Specimens were first brought in by Prof. W. P. Jenney on his exploring expedition in 1876. The exact locality is near French creek, 6 miles east of Custer, in the county of that name. Here it exists in great quantity and of fine quality, outcropping along a ledge for 500 feet in a vein varying in thickness from a few feet up to 60. The color, as usual, ranges through many shades, from faint pink or even white, to the tint of a ripe watermelon, and in places alters completely within a few inches. Contrary to the general opinion, there is no evidence of its fading by exposure to light, for outside portions, and even rolled bowlders, show in some cases a fine deep coloring.

Amethyst is a variety of quartz of a deep purple or bluish violet color, shading almost to pink. Like ordinary quartz, it is composed of silica, and the coloring is due to the presence of oxides of managanse and iron. Its hardness is about 7, and its specific gravity is slightly above 2.65.

Fine gem material has been found in the United States, though nowhere is it mined with any regularity. The localities from which the finest specimens come are in Maine, Pennsylvania, North Carolina, southern Virginia, and northeastern Georgia, and several discoveries have been made recently in the West. The main developments within the last few years are the following:

Deer Hill and Stow, in Maine, were noted localities some time ago, but have not yielded much lately. At Denmark, however, in the same state, Mr. G. R. Howe obtained many fine crystals, and had a number of gems cut that were very richly colored—equal to any from the Ural mountains.

Another old locality was Upper Providence township, in Delaware county, Pa. Here a large amount of amethyst was obtained that yielded gems of the finest quality, one of which was of 33 carats; and another, still larger, is in the Lea collection in the National Museum at Washington.

Virginia has only recently come into notice as a possible source of amethyst production. Its occurrence, in beauti-

ful crystals, was announced at two points in Goochland county, by Mr. G. L. Chase, and also near Lovingston, Nelson county, by Mr. Benjamin Dillon. In 1902 a promising locality was discovered and opened in Amherst county, near Lowesville.

The western sources of production are chiefly in Montana. A crystal weighing 12 pounds was found at Granite, and in 1900 remarkable discoveries were made in Jefferson county, some 22 miles southeast of Butte, by Mr. A. P. Pohndorf. Here amethyst occurs in fine crystals, curiously mingled with quartz both colorless and smoky. Crystals of black tourmaline so penetrate the quartz as to render it opaque. The amethyst itself is free from these inclusions, though sometimes it forms parts even of the same crystals.

In Colorado, amethyst is reported from Cripple Creek and from localities in Park and Mineral counties, but no special data have been given as to these occurrences.

Good material has been brought from two or three points in Alaska, but there has been no development as yet.

Natural rolled pebbles of quartz, of various colors, are often beautiful, sufficiently so at times to be applied to some uses in the arts or for cheap jewelry. At many points along the Atlantic coast, visitors to the seaside resorts gather pebbles of attractive aspect, especially those of colorless transparent quartz, and sometimes have them cut as souvenirs. These are the so-called Cape May diamonds, and there is quite an industry at many resorts in gathering pebbles to cut for gems, seals, etc. A good deal of fraud is also practiced upon visitors, all manner of ornaments being sold as material found in the vicinity. At Narragansett Pier, R. I., some local dealers and lapidaries have been known to sell foreign cut quartz, cairngorm stone, topaz, crocidolite, Ceylonese moonstone, and even glass as stones from the beach. In some cases pebbles found by visitors and entrusted to lapidaries for cutting have been replaced by cut stones imported from Bohemia, Oldenburg, and the Jura, where cutting is done on such a large scale and at such low wages that the stones can be brought here at one tenth of the cost of cutting the material itself, in the case of quartz, having but small value. The annual proceeds from

the sale of cut stones, and the money expended in cutting them at these and other resorts throughout the country, may amount to $20,000 or more a year, and the sale of specimens to a like sum.

Another ingenious fraud has been practiced at Hot Springs, Ark., where clear, rolled pebbles of colorless quartz, found on the banks of the Ouachita river, are in special demand, being more valued for cutting than the crystals of the vicinity, because of a mistaken idea that they will cut into clearer gems. Fine pebbles of this kind are scarce, and so they have been artificially imitated by putting a number of crystals into a box, which is kept revolving by waterpower. In a few days mutual attrition has rolled and roughened the crystals into beautiful pebbles—so beautiful, indeed, that an expert can distinguish them from the real ones by their more perfect whiteness of surface.

Along the coast of California and Oregon there are various localities where many very attractive pebbles of chalcedony, agate, etc., are found. The principal beaches are at Crescent city, at the northern extremity of California; Pescadero, some 28 miles west of San José; and Redondo, a few miles south of Los Angeles. These pebbles are very abundant and in great variety, and are much sought by visitors. Many are put up and sold in bottles of water, to preserve their bright colors and markings and their translucency; and many are drilled and strung to make chains and similar fancy ornaments. Some of those at Pescadero are little hollow geodes of chalcedony, occasionally an inch long, inclosing a liquid with a moving bubble. These little natural sealed flasks are found also on the beach at Tampa, Florida.

These minerals are forms of quartz (silica), but differ from those previously noted in being noncrystalline, or at least the crystalline structure, if present at all, is only discernible by the microscope. They are also never transparent, but vary from translucent to nearly opaque. With the exception of colorless chalcedony or white carnelian, they are variously and often richly colored by metallic oxides, principally those of iron and manganese, and furnish a number

of semiprecious stones that have long been favorites in jewelry and art work.

There are many localities in the United States where handsome agates and chalcedonies occur, and some of these may hereafter be commercially developed. In the agatized forest, or Chalcedony park, of Arizona, an area of many square miles is strewn with logs and trunks of an ancient growth of trees, now completely altered to silica, and stained with the richest and most varied hues by the oxides above named. Silicified wood is by no means uncommon, but it rarely presents such beauty of coloring as here, where fallen and broken trunks many feet in length and ranging up to as much as 4 feet in diameter, with the woody structure perfectly visible, are converted into agate and chalcedony of every mingled shade of red, brown, and purple. When polished this makes one of the most beautiful and interesting ornamental stones in the world, and has attracted great admiration abroad as well as in this country.

The locality is in Apache county, Ariz., a few miles south of the Southern Pacific railroad from Adamana station, not far from the town of Holbrook. It consists of three open valleys or eroded areas among a wilderness of mesas and buttes. The logs, more or less shattered into pieces and fragments or cylindrical cross sections, lie along these valleys by thousands, having been washed out of the rather soft sandstone that formerly covered the whole region and which still remains in the intervening hills and buttes. At some points the logs may be seen in place in the sandstone, especially at the celebrated chalcedony bridge, where a large trunk spans a gully worn in the side of a small hill. Geologically these beds belong to the Triassic formation, equivalent to the brown and red sandstones of New Jersey and the Connecticut valley. But the trees grew at a somewhat earlier time, and were overthrown and buried in the sandstone when that was laid down by an invasion.

Another semiprecious stone which has been developed in the United States within the past decade is chrysoprase, a chalcedony of a light green color, caused by the presence of oxide of nickel. This stone has been highly valued for cen-

turies, but is of rare occurrence, and most of that used in jewelry and in the arts has been obtained from Silesia. Its existence in North America had been recognized at some points before, but the only promising locality was at Riddles, Douglas county, Oreg. Mr. George W. Smith, a surveyor, obtained specimens in Tulare county, Cal., as far back as 1878. These he submitted to experts, who pronounced them to be true chrysoprase. The first who positively identified them as such, by actual determination of the nickel oxide, was Mr. M. Braverman, of Visalia, Tulare county, who is well known for his enthusiasm in locating and collecting California minerals. From that time specimens were gathered and sent quite widely to museums and cabinets; but not for some years was its commercial value appreciated. When that became known, systematic development was attempted, the neighborhood was prospected, and other occurrences discovered, so that now there are not fewer than five localities in Tulare county where chrysoprase is known to occur. The first of these to be discovered was the one at Venice Hill, 12 miles northeast of Visalia; the others are on Stokes mountain, on the Tule river, on Deer creek, and at Lindsay, 16 miles south of Visalia. Mr. Braverman has been active in the search for these localities, and has presented to the California state mining bureau a very fine specimen from the last named place. The veins which it forms are of no great thickness, and much of the material is flawed and cracked, or too pale to be valuable. Still a large quantity of fine chrysoprase has been obtained and cut from these several localities, especially the last two and the first.

A promising locality has been discovered in North Carolina, at Morganhill, in Buncombe county, some 16 miles from Asheville. Here it occurs in several parallel seams or veins quite near to each other; the color is pale at the surface, but becomes deeper below. No extensive work has yet been done here, although some very rich green material has been cut and placed on the market, and the outlook is favorable.

The name moss agate is applied to a variety of translucent chalcedony, usually nearly colorless, that is penetrated by minute branching or dendritic (tree like) crystallizations of oxide of manganese or of iron, the former black, the latter brown

or reddish. It has long been a favorite semiprecious stone in Europe and the east, but large pieces are rare. Small rounded nodules of it are abundant at various places in the west, particularly in Wyoming. In 1893 large masses were found near Hartville, Wyo., occurring in a vein 8 or 10 inches thick in limestone. Slabs of two or three feet in length were taken out. The translucent white slabs, with moss-like markings in black, are very beautiful.

Two other localities in which moss agate has been found are reported in Wyoming, one 47 miles and the other 75 miles northwest of Cheyenne. No important developments, however, appear to have been made at these points.

SULPHUR AND PYRITE.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York City in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is the assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

Sulphur has been known to mankind from the earliest records of history. It is one of the most important elements that comprise the earth's crust, and occurs in a free or uncombined state in many countries, forming the mineral sulphur, more commonly known in commerce as brimstone.

The element is insoluble in water and nearly so in alcohol and ether, but is quite soluble in carbon disulphide, petroleum and benzine. It burns in air with a blue flame, and is oxidized into sulphur dioxide or sulphurous acid. It exists in two distinct crystalline forms, and also as an amorphous variety. These modifications are characterized by differences in specific gravity, in solubility in various liquors, and in many other respects.

Sulphur is a pale yellow, brittle, crystalline solid, with a resinous luster, is almost tasteless, and emits a peculiar characteristic odor when rubbed or warmed. It is a nonconductor of electricity and an extremely bad conductor of heat. When very gently warmed, even by being grasped in the hand, it may be heard to crack by the mere warmth, and will ultimately fall to pieces. At a temperature of 114.5° C. it melts into a clear amber colored and moderately mobile liquid; on raising the temperature of this liquid, its color rapidly darkens, and at the same time it loses its mobility until at a temperature of about 230° C. the mass appears almost black, and is so viscous that it can no longer be poured from the vessel. As

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the temperature is still further raised, the substance, while retaining its dark color, again becomes liquid, although it does not regain its former limpidity. At 448° C. the liquor boils and is converted into a pale yellowish brown colored vapor. In cooling the same changes occur in reverse order. The atomic weight is 32. The specific gravity of ordinary octahedral sulphur is 2.05; of prismatic sulphur, 1.96.

Sulphur is used in the preparation of sulphuric acid, in the manufacture of gunpowder, in making friction matches, in vulcanizing rubber, as an insecticide, and in medicine as a laxative and for certain skin diseases.

Sulphur occurs in combination with other elements, forming the large and important groups of minerals, the sulphides and the sulphates. Of the sulphide minerals, the combinations with the metallic elements are of primary industrial importance, and, with the possible exception of the iron sulphides, they form the ores from which many of the base metals are obtained.

Sulphur dioxide (SO_2) is the direct combination of sulphur with oxygen and is found naturally as a minor constituent of the atmosphere, particularly near volcanoes, and over large cities, where its presence is due to the oxidation of the sulphur contained in the fuel burned.

In vegetables sulphur exists in some of the tissues of plants, although not in the woody tissues. In animals it constitutes an essential element of the blood, muscles, skin, hair and other parts.

Hydrogen sulphide (H_2S) and sulphur dioxide (SO_2) are evolved from volcanoes as gases, which are doubtless the products of the action of the water of the ocean which has penetrated to the interior of the volcano upon the molten metallic sulphides that exist there.

The two forms in which the sulphur is marketed are the flour, or flowers, of sulphur, which is a light powdery form of the substance caused by the condensation of sulphur vapor; and brimstone, or sulphur, which is made usually by melting this soft powder and molding the liquid thus obtained into large blocks or cylindrical rods in wooden molds.

Natural deposits of sulphur are sometimes found strati-

fied with beds of clay or rock, but they often occur as what are known as living beds, in which the sulphur is continuously being formed as the result of active chemical decompositions. In such a living sulphur bed the sulphur is produced by the direct action of sulphurous gases, especially hydrogen sulphide (H_2S) and sulphur dioxide (SO_2), which in the presence of moisture (H_2O) react and form water (H_2O) and sulphur (S). These gases emanate in regions of active or expiring volcanoes, and form the so called solfataras, in which the sulphur has been condensed from the vapors formed and has collected in cracks in the lava and tuffs or in the kaolin or clay formed by the corroding action of the acid vapors on the lavas.

From a commercial standpoint, especially for the manufacture of sulphuric acid, the mineral from the solfatara deposits is not regarded favorably on account of its liability to contain arsenic in the form of the minerals orpiment (As_2S_3) and realgar (AsS). Sulphur of this character has been imported from the island of Vulcano, one of the Lipari group, off the coast of Italy. A similar association of arsenic minerals has been reported in the sulphur deposits in Yellowstone national park.

Traces of selenium and tellurium, which are also objectionable in the manufacture of sulphuric acid, occur in the volcanic sulphur deposits in Japan. The only solfatara deposits of commercial importance at the present time are in southern Utah and in the island of Hokkaido, Japan.

The world's supply of sulphur is derived from two principal sources: (1) The deposits of the native mineral sulphur which yield the sulphur or brimstone of commerce; and (2) the deposits of the sulphide minerals—pyrite, pyrrhotite, chalcopyrite, sphalerite, and other sulphides—from which is derived the sulphur dioxide gas used in the manufacture of sulphuric acid. In addition to these two natural sources of sulphur, there are several artificial products containing sulphur, chiefly in the form of sulphur dioxide gas, in sufficient quantity to admit of commercial utilization. There are also lead, copper, and other mattes from the furnace treatment of various lead and copper ores and alkali waste from chemical works engaged in manufacturing soda.

During recent years, however, several thousand tons of sulphur have been produced annually in England from the accumulated alkali waste of the Le Blanc soda process. This manufactured product is known as chance-claus, or recovered sulphur. The process of its manufacture reproduces, in many respects, the chemical reactions by which natural sulphur is formed from gypsum.

The development of the sulphur mining industry in the United States has been of very slow growth, owing principally to the cheapness with which the refined product can be imported from Italy. In recent years nearly the entire supply has been obtained from the enormous deposits in the island of Sicily, which supplies, as well, by far the greater part of the rest of the world's demand. The deposits of sulphur which have been worked in the United States are limited in number. The states from which the domestic supply of native sulphur is derived are, in the order of the quantity of their output, Louisiana, Nevada, and Utah.

In Louisiana an immense deposit of sulphur of the gypsum type occurs in Calcasieu parish, 230 miles west of New Orleans and 12 miles from Lake Charles. This is unquestionably the most accessible of the American deposits, and, in all probability, it is the richest as well. Exceptional difficulties have been encountered in developing the mine, owing to quicksand and gravel which overlie the mineral. As proved by a number of drill holes the bed of sulphur is from 110 to 125 feet in thickness, the upper level being about 350 feet below the surface.

In the working of the Frasch process, a well is sunk by a drill precisely in the same way as for petroleum. This well is cased with an iron pipe 10 inches in diameter, which enters the rock overlying the bed of sulphur for a distance of 10 feet, the joint being subsequently sealed as well as possible by molten sulphur in order to exclude water. Inside the 10-inch pipe is placed one of 6-inch diameter; inside the latter, one of 3-inch diameter; and, finally, inside the 3-inch pipe, one of 1-inch diameter. The well itself is carried down to the bottom of the sulphur bed, and the 6-inch and smaller pipes are extended nearly to the bottom of the well. The inner pipes are recover-

ed when the well is abandoned. The method of extracting the sulphur is as follows: Steam at a temperature of 330° F. is forced down the 10-inch and 6-inch pipes under a corresponding pressure. When the steam comes in contact with the sulphur (which at 284° F. becomes liquid), the latter melts and collects in the well as a thin liquid of a specific gravity of about 2. At first the molten sulphur was pumped out through the 3-inch pipe in a manner similar to that followed in pumping petroleum from a well, the working valve being formerly of aluminum, which is not affected by sulphur. It was found, however, that the aluminum was not strong enough to withstand the shock of the heavy column at the change of stroke, and the method had to be abandoned. Later, the 1-inch pipe referred to above was introduced into the 3-inch pipe, and through it compressed air was forced. The bubbles of air mixed with the sulphur reduce the specific gravity of the column of sulphur and cause it to rise with rapidity. The sulphur produced is practically refined sulphur, and finds a ready sale on account of its purity and attractive appearance.

It is not practicable to ascertain precisely what occurs at the bottom of the well, but it may be assumed that as the sulphur melts out of the bed it forms a more or less pear shaped cavity, which becomes larger and larger, until finally the increased surface exposed to the water is sufficiently great to reduce the temperature of the water below the melting point of the sulphur, while the impurities of the bed collect on the bottom and the sides of the chamber and protect the sulphur still unfused from the melting action of the heated water. If the bed of sulphur is very pure, the chamber might become quite large in size, when the unsupported overlying roof would fall and allow the water to escape through the overlying beds.

Although the Frasch process is very ingenious and the inventor deserves great credit for working out the numerous details, yet its application to the deposits of sulphur has greatly injured them, since the exploitation of the deposit by shafts and the common method of underground mining has now become fraught with danger, owing to the uncertain extent of the

openings from which the sulphur has been dissolved by the Frasch experiments. In view of the heavy flow of water which may be expected through certain of the strata this uncertainty is an element of great peril.

In Nevada sulphur occurs at Rabbit Hole Springs, 35 miles from Humboldt House, in Humboldt county. The deposit is of the solfatara type; and the sulphur, associated with gypsum, etc., fills the craters of a few extinct hot springs. The sulphur rock is in beds of considerable thickness and extent, included between limestone and magnesian rocks. The ore occurs in masses of various sizes up to several hundred pounds in weight, which are mixed with clay among heaps and layers of ashes and light gravel. The ore is mined by adits and drifts run in from the level of the wagon road, which extends entirely around the hill at a considerable elevation. All rock containing more than 8 per cent of sulphur is mined, and the product is taken to the refinery and refined in iron kettles heated by dry steam. The refined product is carried in wagons to Humboldt House and shipped thence by rail, chiefly to the powder factories and acid makers on the Pacific coast.

The deposits which are the source of most of the sulphur mined in Utah are located in Beaver county near the Millard county line. They were known to the early pioneers, who obtained small quantities of nearly pure sulphur from the numerous caves in that vicinity. Soon after the year 1870 the claims were located under the mining laws, and a small refining furnace was installed which was worked intermittently until the year 1891, when the property changed owners, and the plant was modernized and enlarged. Under the new management the mining operations of the company have been continuous and successful. The ore is removed by open cutting, and the furnaces are worked during the summer only. Four of the six stacks in the refining plant are generally operated at a time, and about 50 tons of 20 per cent rock are treated daily, yielding the refined product in the form of rolled sulphur, which is sold as such or is ground in mills to make flour sulphur.

It has been proposed to separate sulphur from the ore by heating it with hot air, with steam under pressure, or with superheated steam. But these methods have been unprofit-

able on account of the cost of fuel in those regions where sulphur occurs. Sulphur may be extracted from the ore by a solvent, such as carbon disulphide, which may be recovered afterwards, but this method necessitates an expensive plant. For some ores a treatment with a solution boiling above the melting point of sulphur has proved successful. The ore is placed in an iron basket or crate in a boiling solution of calcium chloride, which boils at 125° C. The sulphur melts and flows away from the matrix of stones, etc.; passing through the meshes of the basket and falling to the bottom of the tank, it is drawn off and cast in molds. After it is melted out, the basket of hot stones is lowered into a tank of water. which is heated by the stones, while it removes the adhering calcium chloride from them. This warm water is then used to replace that lost from the boiling calcium chloride solution. This process causes noloss of sulphur as sulphur dioxide, and no nuisance is created, while a fairly pure product is obtained. The calcium chloride used is a waste product of the ammonia soda industry.

In the United States, the extraction of sulphur by means of superheated steam has been tried, and an excellent quality of sulphur has been obtained without formation of any sulphur dioxide. The cost of fuel in the west, however, is an obstacle to the further development of this method. In Louisiana, as mentioned earlier in this paper, steam is forced under pressure, through driven wells or tubes, into the sulphur deposit, which partly refines the sulphur, liquefied by the heat. The molten product is forced to the surface by the steam pressure through a small pipe inside of the steam pipe. Generally the method of extracting the sulphur from the ore, and at the same time of partially refining it, is to treat the ore in a cylindical or slightly conical cast iron vessel of a capacity of about 5 tons of ore. Steam inlets are provided at the top and bottom, also a bottom valve through which the melted sulphur is withdrawn and cast into molds. The size and the form of this refining vessel depends to some extent upon the nature of the material to be treated. If the ore is porous, a higher vessel of greater capacity can be used, and with ores that increase their

volume considerably from the action of the heat, the bottom of the vessel should be made of much larger cross section than the top, in order to facilitate the discharge of the spent ore after the sulphur has been extracted. The steam jets are so arranged that the melted sulphur cannot accumulate at any point within the vessel except at the bottom. If properly arranged and operated the extraction of sulphur by means of superheated steam should be accomplished with the loss of not more than from 1.5 to 2 per cent of the quantity of sulphur treated.

The name pyrite is derived from a Greek word meaning of the nature of fire, and alludes to the property possessed by the mineral of producing sparks when struck with a hard substance. Specifically, the name pyrite is restricted to the isometric crystalline form of the native iron bisulphide mineral (FeS_2) containing 46.6 per cent of iron and 53.4 per cent of sulphur. The mineral marcasite is also a native iron bisulphide (FeS_2) of identically the same chemical composition as pyrite, but it occurs in crystals of the orthorhombic system of crystallization. In a general sense, pyrite includes that class of native minerals in the massive or crystalline form composed of a metallic sulphide or arsenide, or both. Iron, copper, nickel, and cobalt pyrite are the principal minerals of this class.

Pyrite occurs abundantly in rocks of all geologic ages, from the oldest crystalline to the most recent alluvial deposits. In crystalline formation it usually occurs in small cubes, pyritohedrons, or in more highly modified shapes; also in irregular spheroidal nodules, and in the massive form in clay slate, argillaceous sandstone, coal formation, etc.

Pyrite is used principally in the manufacture of sulphuric acid. Recently it has also been used in pyrite and allied smelting processes and, to some extent, in making sulphur dioxide gas for use in bleaching wood pulp. In vulcanizing rubber and in the preparation of medicinal compounds the use of pyrite is impracticable.

The deposits of pyrite in the United States are quite numerous and widespread. The largest deposits so far discovered are at Mineral, Va., and Charlemont, Mass. Deposits are also found in Alabama, California, Georgia, Indiana, New

York, and Ohio. The mineral was mined in these states in 1902. Virginia supplied nearly one half of the total. The production in Indiana and Ohio was in the form known as coal brasses, obtained as a by-product in the mining of coal. The total quantity so produced, however, was but a small proportion of the total output of the United States. It is not probable that the production of pyrite from this source will ever become of importance.

There are many other deposits of pyrite in the United States, but they have not been exploited because of the impure or low grade quality of the ore and the excessive cost of mining and of transportation both to and on the railroads leading to the centers of consumption. Some of the ores not now deemed of sufficient value to be worked for their sulphur content will eventually be profitably treated by modern methods. In the southern states particularly are many deposits of this character, which could produce enormous amounts of sulphuric acid in this manner at prices lower than the present average prices at the seaboard. A condition which has served to retard the growth of the production of the domestic ore lies in the fact that foreign ores can be imported and accumulated at the seaboard and shipped inland in quantities sufficiently large to secure very low freight rates.

A promising prospect for the pyrrhotite ores of the south lies in the feasibility of their utilization for the manufacture of sulphuric acid. It is claimed that the sulphur contained in these ores can be so effectually removed that the residual product will be of value in the manufacture of pig iron or even of steel. For this purpose the cinders or residues from the roasting of pyrite for the manufacture of sulphuric acid have been utilized to advantage. It is well known that the residues from Spanish ores treated by the Henderson process have been sold either in the form of fines or briquetting and utilized in the manufacture of steel, but in the United States roasted pyrite residues have not yet been utilized for the manufacture of iron on account of the large percentage of sulphur remaining in them after treatment in the chemical works. If pyrite residues could be roasted so that the amount of sulphur remaining after treatment would be so small as to permit of their

utilization for the manufacture of pig iron, there would result an annual saving of many thousand tons from what is now a waste product. As yet, however, the recovery of sulphur and iron from these ores is in an experimental state.

Other experiments have recently been conducted for the utilization of the by-product gases resulting from the roasting of zinc blende ores, the practicability of which has been demonstrated with financial profit at the zinc plants of Peru and Lasalle, in Illinois, and of Argentine, in Kansas. It is feasible to save from 25 to 28 per cent of the sulphur content of the zinc ores during the roasting, which yields a product containing not more than 2 per cent of sulphur. By subsequently roasting this product—cinders, as it is called—in the Chase or other type of special roasting furnace, the remainder of the sulphur will be expelled, and the dead roasted zinc ore will then be in proper condition to permit of the extraction of the zinc at very low cost. There is an immense supply of sulphur in the zinciferous sulphide ores of Arkansas, Colorado, Kansas, Kentucky, Missouri, and other states, and it is well within the range of probability that ere long the tonnage of sulphur derived from pyritiferous ores will be largely augmented by the utilization of the sulphur contained in these zinc sulphide ores.

An important factor in the development of the pyrite industry is the demand for sulphuric acid in the treatment of phosphate rock, and in the refining of petroleum. Since a chemically pure sulphuric acid is not essential for these purposes, the acid made from pyrites serves quite as well as that made from sulphur. Another field for the future extension of the utilization of the pyritiferous ores lies in the making of sulphur dioxide gas for use in bleaching wood pulp, which is the basis of the manufacture of paper by the sulphite process. Heretofore American manufacturers of paper using this process, with one or two exceptions, have been limited to the use of sulphur for making sulphur dioxide gas, although in Europe a considerable quantity of pyrite has been thus utilized. It is quite probable that the difficulites that have heretofore existed in the way of utilizing pyrite in the bleaching of pulp will be overcome in the near future. When this becomes an accomplished fact it will open up a large field for the consumption

of pyrite in New York state, and also of the lean cupriferous pyritic ores of the New England states. Where the conditions are favorable for deep mining and concentration and for shipment to the numerous paper mills of that section, constant and large supplies of sulphur will thus be guaranteed at prices much lower than can be expected from outside sources.

The manufacture of sulphuric acid is of great industrial importance, as the acid is of primary importance in the manufacture of phosphate rock fertilizers and in the refining of petroleum. It is also required in the manufacture of other acids and chemical salts, and has a very wide field in the making of alizarin dyes, artificial indigo, and many other important chemical salts. Of the immense quantities of sulphuric acid made yearly, the greater part does not appear on the market; because of the expense and difficulty of shipping it, consumers of large amounts generally make their own acid.

Until a few years ago the total quantity of ordinary sulphuric acid produced in the world had been obtained by burning crude sulphur in air, the resultant sulphur dioxide gas being then passed, together with steam and an oxidizing agent, generally nitric oxide, into lead-lined chambers, where these gases react on one another and form the dilute acid, which is subsequently purified and concentrated to the desired degree of strength. This process is called the lead-chamber process, but a newer and more satisfactory process is the contact process, in which the sulphur dioxide gas, in the presence of so-called catalytic substances (platinum sponge, platinized asbestos, iron oxide, etc.) is directly oxidized to sulphur trioxide (SO_3), which is then absorbed in water to form sulphuric acid of any degree of strength. Recently it has been found more economical in making sulphuric acid to utilize the sulphide minerals as the source of sulphur dioxide gas. In this manner the more costly brimstone is reserved for purposes other than acid manufacture, and for which the sulphide minerals would not be applicable.

The use of pyrite as a raw material in the manufacture of sulphuric acid was first proposed by an Englishman named Hill, who obtained a patent for the process in 1818. It was not until 1838, however, when the price of crude sulphur was

nearly trebled by the French firm who had purchased from the Sicilian government the monoply of the sulphur exportation from that island, that the use of pyrite by acid makers attained any importance. In the United States, which leads the world in the consumption of sulphur, this substitution of pyrite for sulphur in acid making has continued steadily during the past twenty five years, and owing to its cheapness and widespread occurrence, pyrite has almost completly replaced the crude sulphur that was formerly used almost exclusively. This change in acid making has resulted largely from the treatment of phosphate rock by sulphuric acid, by which it is made into valuable fertilizer, and also from the use of the acid in the refining of crude petroleum. For these purposes the use of a high grade, pure sulphuric acid is not essential. Unrefined sulphuric acid made from pyrite is generally contaminated with arsenic, and frequently with the additional impurities, copper, zinc, and selenium, but not in sufficient quantities to bar its use in preparing fertilizers or in refining the crude petroleum. The impurities, too, may be removed if desired, and a pure acid produced.

To give some idea of the large quantities of the acid consumed in these industries, it may be stated that 1 pound of acid of chamber strength is required to convert each pound of crude phosphate rock into acid phosphate or commercial fertilizer, and in one year 1,500,000 long tons of the crude phosphate rock were mined. In refining crude petroleum each gallon of commercial petroleum (kerosene) requires 1 pound of sulphuric acid of a strength of 66° B. for its production, and during 1902 the output of crude petroleum in the United States amounted to over 89,000,000 barrels, each of 42 gallons capacity. In estimating the quantity of acid consumed in these two industries alone, any calculation based upon figures of production, less imports, both of crude petroleum and phosphate rock, must necessarily be tentative and not even closely approximate, for the reason that it is impracticable to ascertain the exact quantities of stock of crude material on hand at the beginning and at the close of a year. For practical purposes, however, it may be assumed that the consumption of sulphuric acid in the United States at the present time is approximately in the

following proportions: For the treatment of phosphate rock, 50 per cent; for refining crude petroleum, 38 per cent; and for use in the chemical trade, 12 per cent.

In making sulphuric acid from pyrite, pieces of the mineral ranging in size from several inches in circumference to extreme fineness are burned with access of air in a furnace, of which there are many forms, each suited for some special physical or chemical characteristic of the ore. As a result of the burning, or oxidation, the sulphur content of the pyrite or pyritiferous ore is converted into sulphur dioxide gas. When the ore contains over 30 per cent of sulphur, the heat generated by the oxidation of the sulphur is sufficient to maintain combustion without fuel. The sulphur dioxide gas produced in this manner is purified, and subsequently converted into sulphuric acid, either by the chamber process, in which the oxidation is accomplished by nitric oxide gases and steam, or by the contact process, previously described.

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BY JOSEPH HYDE PRATT.

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Mica, in some form or other, is probably familiar to everybody because it is so very widely distributed in nature, being a component part of many of the crystalline and sedimentary rocks. Its commercial value is dependent upon its occurrence in blocks or masses that are capable of being split into sheets a square inch or more in size. Deposits of commercial mica occur for the most part in pegmatitic dikes or veins which are found in granite and hornblende and mica gneisses or schists. These dikes or veins vary in thickness from a few inches to several hundred feet and are often very irregular, having arms or veinlets branching off in many directions. In character these dikes are similar to granite, and sometimes they are called coarse granite, and if we could conceive of the constituents of granite being magnified a hundred times or more we would have an appearance similar to a pegmatitic dike.

The mica in these pegmatitic dikes will seldom average over 10 per cent of the contents of the dike and sometimes will be as low as 1 per cent. Often a dike will have the appearance of containing a very high percentage of mica on account of a number of blocks being clustered together in bunches almost touching each other, while in another portion of this same dike the mica will be almost entirely absent for a distance of from 5 to 20 feet; thus the general average of mica in the dike will be from 1 to 10 per cent only. Of the mica obtained from these dikes, usually only from 5 to 25 per cent can be cut into sheet or plate mica. The average is probably about 10 per cent. Occasionally large quantities of mica are mined in which there is not over 1 per cent that can be made into sheet mica. These commercial occurrences of mica are not very

abundantly distributed throughout the United States, although rocks in which mica is one of the chief constituents are very common. At the present time deposits of commercial value are known to occur in Alabama, Arizona, California, Colorado, Connecticut, Georgia, Idaho, Maine, Missouri, Nevada, New Hampshire, New Mexico, New York, North Carolina, Rhode Island, South Carolina, South Dakota, Vermont, Virginia, and Wyoming; and in Arkansas there are also deposits which may become of commercial importance. In most of these states the deposits were not worked in 1902. In some of them the deposits were not available on account of their distance from railroads, this being especially true of those in Arizona, Colorado, Nevada, New Mexico, and Wyoming. In others little has been done owing to the uncertainty of the price and the demand. Many of the deposits of Maine have only recently been opened, and therefore have not been extensively developed.

Mica was first produced in the eastern states along the Appalachian mountains, and twenty years ago mining was carried on vigorously in Connecticut, New Hampshire, North Carolina, and Virginia. In the eastern field the principal mining is in North Carolina, which, since the beginning of the mica industry in the United States, has been the chief producer of the mineral. At just what time the first work was done on the mica deposits of North Carolina is uncertain, and since there is no record of the old mining and none of the inhabitants of this section have any information whatever regarding these old workings, they have been attributed to the Indians. Trees 2 feet and over in diameter have been observed growing from these cuts. Stone implements have been found in some of the old tunnels, indicating the antiquity of these workings. Most of these old mines are located in Mitchell and Yancey counties.

Of the north central states, South Dakota has been and still is the state in which the largest quantity of mica is produced; while of the western states and territories, New Mexico has for a number of years been the largest producer, but is now likely to have to give way to California. These California deposits have only been opened up within the past few years, but the mining is now being carried on quite extensively. At

the present time the Nevada deposits are too isolated to warrant mining on an extensive scale. The completion, however, of the railroad, which is being constructed from California across Nevada and Arizona to Utah, will make these deposits more available for commercial purposes.

The uses of mica are somewhat varied; there are two forms in which it is used, (1) sheet or plate mica and (2) scrap mica.

Mica is cut into sheets of various sizes which are used for stoves, lamp chimneys, incandescent lights, and in electrical apparatus for insulation purposes. While the use of this sheet mica for stoves has decreased very rapidly during the past ten years, there has been a corresponding increase in its use for electrical apparatus. It is also used in place of glass in the manufacture of a great many novelties and in many respects increases the usefulness of the articles made. There was formerly a considerable demand for the larger sheets of mica, but these have been replaced to some extent at the present time by a manufactured product known as micanite, which is made from very small, perfect pieces of mica rearranged and cemented together into larger sheets. For some purposes these manufactured sheets are as satisfactory as the natural ones and are, of course, much cheaper.

The value of sheet or plate mica varies with the size of the sheet and is from 2 cents to $3 per pound. The values of from 2 to 5 cents per pound are for the small disks and rectangular sheets that are cut by machinery and are used extensively in electrical apparatus. The larger sheets are cut by hand and considerable skill is required to cut the largest pattern possible from the crude block of mica.

The waste or scrap mica not suitable for cutting into sheets of even the smallest size has a value when ground to a flour, which is used in the manufacture of wall papers, lubricants, fireproofing material, artificial snow, novelties, etc. Coverings for boiler tubes and steam pipes are also manufactured from particles of scrap mica which are not ground but are broken into pieces of approximately the same general dimensions, one half by one fourth of an inch. These are then arranged with their longer dimension and face parallel to the length of a wire net coil, pressed into the shape of a pipe or tube,

against which the layer of scrap mica is kept tightly in place by means of heavy canvas. A number of the states, especially North Carolina, offer very favorable locations for the erection of plants to manufacture products from scrap mica, as there is usually a supply of available water power near the deposits.

The commercial value of scrap mica before it is ground is from $8 to $10 per ton, delivered at the railroad, and it is this value that has made it possible to work some of the mines that otherwise would have been shut down, for in some cases this waste mica represents from 75 to 95 per cent of the mica mined. After being ground, the mica is worth from $40 to $60 per ton, according to its mesh.

There are a number of minerals, especially quartz and fieldspar, associated with the mica, which in some instances should prove of considerable commercial value as by-products in mining the mica, provided water power for grinding these minerals can be secured near the source of supply. Occasionally some of the gem minerals, as beryl and tourmaline, are found associated with the mica, and furnish some very handsome cut stones. Some of these pegmatitic mica bearing dikes are rich in the variety of minerals that they contain, while others have very few besides these typical of a pegmatitic dike. Between forty five and fifty different minerals have been found associated with mica at the different mines throughout the country.

The small production of mica in the United States as compared with the importation is not due to a deficiency in the supply of the mineral in this country. It is undoubtedly true that in the Appalachian region, especially in the southern area, there are many good deposits of mica yet to be discovered which will yield as rich returns as many of those that have already been mined. It is also true that many of the mines that were worked so extensively twenty years ago, especially those in North Carolina, still contain good deposits of mica which the former owners were prevented from taking out on account of the presence of water, which they were unable to control with the means that they had at hand. Any increase in the duty on mica or any considerable decrease in the im-

portation of mica from India and Canada would cause an increase in the price of mica, and would result undoubtedly in a large and immediate increase in its production in the United States.

PETROLEUM.

BY F. H. OLIPHANT.

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Much speculation and controversy have been aroused among chemists and geologists as to the origin of petroleum, but no complete and satisfactory solution of the problem has yet been presented. Numerous theories have been advanced as to the original source of the carbides and hydrocarbons and their combinations, entering into the formation of petroleum, and many scientists of note have a particular theory, but there appears little possibility of reaching an agreement in the matter in the near future. Experiments in the laboratory have been made so as to combine the elements artifically and the resultant, in most instances, has been a liquid, which in appearance and composition is very similar to the natural petroleum. Petroleum has also been produced by the distillation of shales, and there are many upholders of the claim that the formation of petroleum is due to the natural distillation by internal heat of the shales and hydrocarbons found in the earth's crust. Its origin is one of the unsolved problems.

The various theories advanced by men of science to account for the formation may be in most cases narrowed down to two, each of which has found numerous supporters. These are—first, its physical origin by the distillation of organic matter in the sedimentary strata, either animal or vegetable; second, its chemical origin from inorganic matter or direct production by the decomposition of carbides through the action of steam deeply buried below all sedimentary strata.

In all of the known fields of the world the occurrence of petroleum is limited to comparatively small areas. The area of the same strata in which the petroleum is not found invari-

ably covers a vastly greater area than the portions that are productive. This is the case also in some instances where the structural conditions may favor its accumulation, and the surrounding slates and shales are similar. When productive rocks can be traced to their outcrop there is invariably no trace of petroleum or asphaltum to be found in them. The wells drilled outside of these favored localities usually find no trace of petroleum or natural gas, although numerous sands may have been pierced which are productive elsewhere and are sufficiently open and porus to be receptacles.

Petroleum, in both its liquid and solid forms, is largely made up of carbon and hydrogen. It ranges from 77° Baumé, or 0.6763 specific gravity, in the case of the lightest naphtha, condensed naturally from natural gas, up to between 1.1 and 1.3 in its more dense and solid form, such as natural asphalt, which usually contains from 50 to 80 per cent of carbon, 6 to 10 per cent of hydrocarbon, and 8 to 10 per cent of sulphur. These solid forms are widely distributed, vary greatly in composition, and are usually associated, in varying proportions, with more or less silica and carbonate of lime.

There is a vast difference in the character of petroleum produced in the United States and in foreign countries, and a great variety in the character of the strata which contain it. The infiltration of the petroleum into different sands and limestones has had much to do with imparting to it the varied physical and chemical properties. However, the structural conditions of these strata and the position they must occupy in order to bring about a concentration of the petroleum are similar in all of the productive fields. Its occurrence in small quantities in strata where the conditions necessary for condensation are wanting has in many instances been the cause of financial loss and disappointment.

The intimate association of the liquid and gaseous hydrocarbons has made it difficult to separate them when one or the other is discussed. The great deposits of petroleum in the Appalachian field are in a series of sand rocks reaching up from the lower Devonian to the upper Barren measures or Monongahela formation, less than 100 feet above the Pittsburg coal, and embraces not less than 50 distinct horizons. The greater

portion of the production however, comes from the Catskill division, upper Devonian, which group is petroleum bearing from northern Pennsylvania, near the northern portion of Venango county, southwest to the Little Kanawha river in West Virginia. In Warren, McKean, and Elk counties Pa., productive sands are found below this group and are largely productive. They extend into south central New York and belong to the middle Devonian formation. The overlying Berea and the Pocono or Big Injun and lower carboniferous sands are above the Catskill group in the geological scale, and are largely productive in West Virginia, southeastern Ohio, and to some extent in eastern Kentucky. The highest series of productive strata in the region east of the Mississippi river are composed of the sands of the upper and lower coal series, which are productive in southwestern Pennsylvania, West Virginia and southeastern Ohio. The sandstone series of the Appalachian division produce 36 per cent of the total production.

Over 85 per cent of the petroleum produced in the United States from the beginning of production up to the present time also comes from the sandstone strata of the Appalachian field. Here there are 40 distinct horizons in 3,300 feet of measures, and the individual beds of sandstone vary from 2 to 120 feet in thickness and differ in texture from an open light colored sand with layers of pebbles, which is very prolific, to sand of a close and hard texture, which it is necessary to torpedo in order to secure production. The highest productive sand of any practical value in the geological scale is the Mahoning, or Dunkard sand of Pennsylvania or the first Cow Run sand of Ohio; the lowest is the Kane sand in Elk and McKean counties, Pa., and the sands of western New York.

The source of the petroleum in the Lima, Indiana field is the Trenton limestone, which has produced very largely since first discovered in this field in 1885. From its first discovery this formation has produced 9 per cent of the total output of the United States. It is productive only in the region which embraces northeastern Ohio and central Indiana, known as the Lima, Indiana field.

The horizon in which petroleum is found in Kansas and

Indian Territory corresponds to that of the salt sand group in Virginia, located in the lower portion of the Pottsville group, resting on the Mississippian limestone, which is in a general way equivalent to the subcarboniferous limestone of southwestern Pennsylvania and West Virginia. All the remaining production west of the Mississippi river is secured from strata that are much more recent, reaching from the Permian to the Quaternary. These newer productive measures consist of much thicker strata—a thickness of 15,000 feet is recorded in localities—and are made up of the recent sedimentary deposits.

The Mississippi river separates the petroleum fields of the United States into two great divisions. The fields east of this line, to an almost universal extent, have developed petroleum with a paraffin base, while the fields to the west have, with a few exceptions, produced petroleum with an asphalt base. Crude petroleum with a paraffin base is generally much lighter and is much more valuable, owing to the greater quantity and superior quality of the naphthas and illuminating and lubricating derivatives it yields, as well as the paraffin, which is secured from the heavier distillates after the lighter products have been extracted.

On the other hand, petroleums with an asphalt base, in most cases, yield only a comparatively insignificant quantity of naphtha and a much smaller proportion of illuminating and lubricating products, which are of inferior quality, while the remaining distillates are principally valuable for fuel and as asphalts. The asphalt petroleums are also usually much heavier and are more difficult to transport by means of pipe lines, so generally applied in the fields producing paraffin petroleum.

These conditions restrict the market for asphalt petroleum, so that in general it is consumed as fuel oil, as distillates for enriching manufactured gas, and as asphalt. There are several exceptions to this generalization, however, as petroleum, in comparatively small amounts, is found in portions of Kansas, Texas, Indian Territory, Colorado, and California, yielding refined products little inferior to the best grades of paraffin oil.

The quality of a portion of the petroleum produced in Kansas and Indian Territory in many respects resembles Pennsylvania petroleum, although the gravity is lower. Separated by intervals of dry or undeveloped territory, there are a number of productive pools, which yield petroleum of a gravity varying from 36° to 28° Baumé, although there is a considerable portion as heavy as 18° to 20°. Nearly the entire production of the lighter grades is sold to the refineries at Neodesha, where an excellent water-white illuminating petroleum is manufactured.

The crude petroleum found in the Florence field, Colo., is of good quality, and comes principally from the Florence pool. This pool produces a petroleum of 31° Baumé, and contains about 10 per cent naphtha and gasoline, 36 per cent illuminating oil, and 54 per cent residuum and loss.

The development in the last two years in Texas, Louisiana, and California of large fields of petroleum specially adapted for fuel, with the probabilities of increased production in these localities in the near future, has added to the interest felt in the practical solution of the fuel problem. The possibility of the successful and economical use of liquid petroleum in the southwest and west has been fully demonstrated in its application to locomotives and stationary engines, as well as to a vast number of manufactories that require a large supply of fuel.

In eastern Europe and southern Asia, along the path of the great ocean commerce and on the waters of the Black and Caspian seas, its use is increasing.

Russia and Borneo, and, to a less extent, Sumatra and Java, furnish the liquid fuel in these far off countries. At Singapore a central supply depot of considerable magnitude has been established within the last few years. There are smaller supplies stored at Seuz, Bombay, Calcutta, Hongkong, and Yokohama. There are a number of large steamers employed on the Gulf of Mexico and the Pacific coast, some of which have used liquid fuel for a number of years and have fully demonstrated its superiority. The number of petroleum burning steamers is rapidly increasing.

The utilization of the entire energy in petroleum will be

accomplished only when it is mixed with the atmosphere under high pressure and exploded in the cylinder direct, in which case the costly, troublesome, and wasteful boiler will no longer be necessary.

During the year 1902 the U. S. navy made some very interesting experiments with petroleum as fuel, which were conducted by a special division of the bureau of steam engineering known as the liquid fuel board, under the direction of Rear Admiral George W. Melville, chief engineer U. S. navy.

Natural lubricating petroleum of the finest grade is often found in the higher strata of the productive series at shallow depths below the earth's surface. It is usually associated with more or less salt water, usually ranges from 32° to 34° Baumé, is not affected, so far as fluidity is concerned, by a temperature of zero or below, and commands a higher price than any other variety of natural petroleum.

The petroleum lubricants differ according to the crude petroleum from which they are made. The chemical composition of crude petroleum from different localities is not the same, showing either that the materials used in its preparation in the earth vary, or that by filtration through different strata different combinations are formed. The largest production of natural crude lubricating petroleum is from the neighborhood of Franklin, Pa., which has long been celebrated for the production of the finest natural lubricating petroleum found in the world.

There is also a large amount of lubricating oil manufactured from Pennsylvania crude petroleum, some of which is mixed with the natural product. No other lubricating petroleum is equal to that produced in the Appalachian field. Its reputation is world wide. Many railroads and steamship lines use it exclusively; the railroads using it in the United States operate 97 per cent of the total mileage.

Years ago the process of distilling natural mineral hydrocarbons was being perfected and vigorously pushed in the eastern states, and cannel shale was imported from England and distilled at refineries near Boston and Portland. On the Allegheny river near Freeport, Armstrong county and Darlington, Beaver county, Pa.; in Ohio, West Virginia, Western

Kentucky, and elsewhere in this country and in Europe, there were refineries or distilling plants endeavoring to supply the demand for an efficient and cheaper lighting oil. The high price, however, prevented its universal introduction. The tallow candle was almost the universal source of artificial light before the great natural deposits of petroleum were known.

The earliest records of the travelers who first penetrated the wilderness of southwestern New York, northwestern Pennsylvania, southeastern Ohio, and south central Kentucky mention the existence of petroleum and natural gas; and the early explorers were guided to these localities by the Indians, who regarded the phenomena with religious superstition. On Oil creek, Pa., there were a number of localities where globules of petroleum and bubbles of natural gas constantly came to the surface of the water. The remains of pits that were cribbed in a crude manner were noted by the early explorers in numerous localities, extending from the mouth of Oil creek to Titusville.

From 1848 to 1856 Mr. Samuel M. Kier, of Tarentum, Pa., bottled the petroleum obtained from his salt well and sold it under the name of Seneca oil, which name it acquired from the Seneca Indians in New York state, who were early acquainted with its medicinal virtues. The partial refining of the petroleum found in the salt brine wells at Tarentum was accomplished by Mr. Kier about the year 1857. Owing to the rude method of refining and the poorly constructed lamps of that day there were many bitter complaints of the odor and smoke of the new illuminating oil when it was first tried.

In 1856, after many failures, a plant at Freeport succeeded in producing an oil that burned with a bright light and was free from odor and smoke. Its introduction was accompanied with difficulty, owing to the dangerous and highly explosive burning fluid that was at that time in use. At this period there were also cannel coal distilling plants at Darlington, Beaver county, Pa., Canfield, Mahoning county, Ohio; Cannelton, W. Va., and Cloverport and Maysville, Ky. In Massachusetts parties who had formerly been engaged in the manu-

facture of whale oil commenced to manufacture a paraffin oil from cannel slate (called boghead mineral) imported from Scotland. About this time small quantities of petroleum were collected by Mr. J. D. Angier, on an island near the mouth of Pine creek on Oil creek, Pa., about $1\frac{1}{2}$ miles below Titusville, from pits arranged one above the other, and by others who used blankets and temporary dams.

On the 30th day of December, 1854, the Pennsylvania Rock Oil company was organized, based upon the purchase of 109 acres at the junction of Oil and Pine creeks, near Titusville, Pa., and the certificates of incorporation filed at New York city and Albany. In April, 1855, the elaborate and favorable report of Prof. B. Silliman, of Yale College, was made public, adding largely to the prospective value of the original company. The eastern capitalists hesitated to subscribe for the stock, as they were uncertain whether a company under the laws of New York could hold land in fee in Pennsylvania. To overcome this difficulty a new company, which retained the original title, increasing the capital stock to $300,000, was organized under the laws of Connecticut, September 18, 1855. A deed was executed to Ashel Pierpont and William A. Ives, of New Haven, who gave bond for the value of the property and promptly leased it for ninety nine years to the new company.

On December 30, 1857, the property was leased to Edwin E. Boditch and Edwin L. Drake, at a royalty of $5\frac{1}{2}$ cents per gallon. This lease was superseded by another to the same parties, fixing the royalty at 12 cents per gallon. Under the terms of this lease the Seneca Oil company was formed, March 23, 1858, which drilled the first well in search of petroleum or rock oil in the underlying rocks, finding it in quantity in August, 1859, at a depth of $69\frac{1}{2}$ feet. The selection of this locality was most fortunate, as nowhere else on Oil creek was petroleum found in quantity at so shallow a depth.

In the year 1860 petroleum was found all along Oil creek to its mouth; also at Henrys Bend, Tidioute, and Franklin on the Allegheny river, and at Smiths Ferry on the Ohio river.

During the year 1861 there was an immense amount of prospecting done, wherever any signs of oil were found, from

central New York to Alabama, and from the Manitoulin islands, in northwestern Ontario, to eastern Kentucky. In Europe, also, arrangements for drilling wells were completed. In Russia, Roumania, Galicia, and India, where oil springs and shallow wells or pits had produced petroleum in limited quantities for many years previously, the idea of drilling wells in order to secure larger supplies from greater depths seems only to have been entertained after the wonderful results were accomplished on Oil creek, Pennsylvania.

The year 1861 was also remarkable for the large flowing wells that were found; several are credited with flowing from 2,000 to 2,500 barrels per day. This caused a remarkable fall in the price, which was as low, in some cases, as 10 cents per barrel, yet without purchasers. The means of storage and transportation, too, were utterly inadequate to handle such quantities. There was some oil secured from old salt wells on the Kanawha and Little Kanawha rivers during this year.

The refiners of cannel coal and cannel slate along the Allegheny river, near Freeport, and elsewhere, soon turned their attention to the refining of crude petroleum and abandoned the distillation of cannel slate. This movement materially assisted in the distribution and consumption of the new illuminant.

The first well drilled for petroleum within the borders of West Virginia was begun in 1859 and finished in May 1860, by the Rathbon Brothers, of Parkersburg. It was located near Burning Springs run; it was drilled by a spring pole, to a depth of 303 feet, at which point the Dunkard or Cow Run sand was penetrated and it flowed 100 barrels per day. This well and tract were sold to a company organized at Parkersburg and a second well was drilled before the close of 1860, which at 300 feet flowed 30 to 40 barrels per hour. The opening of these two promising wells was followed by a great rush of prospectors.

At the height of the development in 1863 the Confederate cavalry forces raided the region and set fire to about 300,-000 barrels of petroleum that had been stored in tanks, and completely frightened away the capitalists who had invested

in the field. The wells were not reopened for several years, when they were found to be unproductive.

In the early history of petroleum production it became necessary to find some other means of transporting the crude oil to the railroads and the navigable streams than in barrels conveyed by wagons. The measure adopted was the pipe line system, the success of which gradually displaced, in a great measure, transportation by rail and boat, and developed a new and remarkably cheap and efficient system of transportation for both the crude and refined product. Pipe lines have proved indispensable to the general industry of petroleum and natural gas. The fact that the manufacturer could supply at a reasonable price wrought iron pipe in sizes up to eight inches in diameter which would stand 1,000 to 1,500 pounds pressure to the square inch, and had almost perfect joints, has aided greatly the economical collection and distribution of petroleum in all the producing regions.

The first petroleum from Oil creek was shipped in barrels made of oak staves banded with hoop iron. The penetrating and salient nature of crude petroleum made it difficult to manufacture barrels that would retain it, even after these barrels had been coated inside with hot glue. The difficulty of returning the barrels when empty, the uncertainty of their condition and the liability to loss by this method of transportation, made it very unsatisfactory, and a source of annoyance to shippers and transportation companies.

About the year 1865 railroads put wooden tanks or tubs for carrying crude petroleum in each end of box cars, a car thus equipped holding from 2,000 to 4,000 gallons. While this improvement was being made by the railroads, transportation by the Allegheny river was also greatly improved by the use of bulk oil boats. These boats, each of which held from 1,500 to 2,000 barrels, were made 130 feet long, 22 feet broad, from $3\frac{1}{2}$ to $4\frac{1}{2}$ feet in depth and were divided into 8 watertight compartments. These were loaded at Oil City and floated down the river to the refineries to Freeport, Pittsburg, Rochester, Mingo, Wheeling, Marietta, and Parkersburg. The latter points also received crude petroleum transported in bulk boats from Burning Springs on the Little Kanawha

river. When there was water enough in the Allegheny river, these empty bulk boats and flats were towed upstream by steam towboats; at times of low water they were towed up by horses.

Though these improvements in transportation, both by rail and by boat, removed a part of the difficulty, there yet remained the obstacles that were experienced in moving the crude petroleum from the wells to the railroad or river. This was still done by team, and the roads were often almost impassable on account of the depth of the mud; the method was at best expensive, and accompanied by great hardship to man and beast. It was chiefly this condition which restricted the amount of petroleum that could be put upon the market.

This condition of affairs suggested the first pipe line. The first one that was a success was constructed by Mr. Daniel Van Syckle, of Titusville, Pa., in the summer of 1865, extending from Pithole to the railroad at the Miller farm, on Oil creek, a distance of 4 miles. In the fall of the same year, Henry Harley constructed a pipe line from Benninghoff **run to** the Shaffer farm. The original line built by Van Syckle was purchased by the firm of Abbot and Harley, who united the two under the name of the Allegheny Transportation company. Both of these lines were successful, much to the discomfiture of the teamsters and roustabouts, who, in some instances, interfered with the operation of the line by cutting or pulling it in two with their teams. A number of arrests followed, and from then on the pipe line was an accomplished fact and an important factor in the collection and delivery of petroleum to points where it could be loaded in tank cars or bulk boats. The growth of long pipe lines was gradual, and it was several years before it was practically demonstrated that long lines could be successfully operated. The improvement in railway transportation by the introduction of the iron tank car was a decided advance over the wooden tanks set in box and flat cars, which for a time answered all the requirements.

The tanks at the wells are connected by a system of small lines or veins which feed the main lines or arteries. These smaller lines usually are concentrated at the lowest portions of the field drained at points known as local pumping stations.

A considerable proportion of the oil finds its way into the tanks at these stations by gravity and is forced to the large receiving tanks at the main station by pumps, which are often driven by natural gas engines, or it flows by gravity through suction lines to pumps into pits and is then elevated to receiving tanks. From the large receiving tanks the petroleum is forced into the main lines at a pressure often of between 600 and 900 pounds to the square inch.

These massive pumps generally represent the highest known mechanical efficiency, having triple expansion engines, Corliss valves, condensers, air pumps, and efficient boilers. They usually develop 300 to 400 horsepower and handle from 30,000 to 35,000 barrels in twenty four hours. The boilers are economical and properly proportioned to this work, showing a duty of 16 pounds of water evaporated at and above 212° F. per pound of crude petroleum consumed as fuel. One pound of good coal will evaporate 10 pounds of water, and 1 pound of natural gas (equal to 20 cubic feet) will evaporate 20 pounds of water under the same conditions.

The main pumping plants are placed from 30 to 50 miles apart, according to the elevation of summits that must be overcome; and by the addition of a parallel line, or loop lines, for a portion of the way the distance can be increased so as to reach localities convenient for fuel or water without greater tax upon the pumps.

There are probably 4,600 miles of main trunk line, from 4 to 8 inches in diameter, in the Appalachian and the Lima, Indiana fields, reaching from northern Tennessee to Parkersburg, Cleveland, Buffalo, Franklin, Olean, and to the seaport cities of New York, Philadelphia, and Baltimore. From the Lima, Indiana field the main lines reach westward to Chicago, Montpelier, Toledo, Lima, and eastward it connects with the Appalachian system.

Kansas has an extensive system of main lines and local lines, reaching in several directions from Neodesha. In California a main line was recently completed, reaching from Bakersfield to a refinery at Point Richmond, near San Francisco, and having a branch line to Coalinga. The length of this main line is 278 miles, and it is connected near its starting

point with about 150 tanks holding 35,000 barrels each. There are other smaller lines in California, extending from Pico canyon to Ventura and connecting Fullerton with Los Angeles.

Texas has in the last few years greatly increased its mileage of main line. There are four lines from 22 to 30 miles in length, reaching from the original field near Beaumont to tide water on the Gulf, and connecting it with Port Arthur and Sabine Pass. Sour Lake and Saratoga are also connected by pipe lines with Beaumont. The Corsicana field in the northeastern part of the state is connected by pipe lines with the refinery there.

As early as 1875 organizations were effected and charters secured for the privilege of building pipe lines to the seaboard. However, these chartered companies at that time confined their operations to the oil regions, where they built numerous lines, usually of a 2-inch diameter, to the several railroads and their branches and to the nearby refineries. The competition among these new pipe line companies for securing the production of the fields began to be marked, especially in Butler county, Pa., and rates for delivery were cut to such an extent that the lines were in several instances operated at a loss. The demand for a consolidation of these competitive companies became more and more emphatic. Under the title of the Fairview Pipe Line a company was organized by Capt. J. J. Vandergrift and George V. Foreman, under the laws of Pennsylvania, the act bearing date of April, 1874. This company was afterwards known as the United Pipe Line association. Into it was merged, from time to time, the other local lines, until it controlled almost the entire system. Gradually the temporary and uncertain characteristics of pipe line transportation disappeared, and more permanent structures were built.

The cheap and efficient method of transportation by trunk pipe lines, permitting the crude and refined petroleum to be delivered at seaboard at a cost much less than it was possible for it to be transported by rail or canal, marked an important era in the history of the petroleum industry. Many problems had to be solved in the construction of the first pipe line. The question of the proper selection of pipes and the making of pipe joints that would not leak under the great pressure; the man-

ner of carrying pipe lines across large streams and rivers and over high, steep hills; the selection of proper localities for tanks and pump stations; the selection of pumps; the cleaning of the pipes when foul; and the method of equalizing distance between pump stations, by the doubling of a portion of the line, so as to equalize the work on the pumps at each station, were all new conditions and demanded the highest mechanical and engineering skill in order to overcome them. These difficulties were all surmounted in a comparatively short time.

The pipe line companies for many years have been the purchasers of the crude petroleum in the older fields. The pipe line company, upon application from the producer, sends an agent, generally known as a gauger, to measure and inspect the petroleum in his tank and run it into its lines. The tanks throughout the field are carefully measured and numbered, and when the oil is accepted and run into the tanks of the pipe line company a card is issued showing the number of barrels to the credit of the producer. Every tank is carefully gauged and numbered and a table prepared, which shows the number of barrels it contains for every inch of liquid from top to bottom. The temperature of the crude petroleum is also recorded and the contents of the tank examined for water. After measuring the petroleum the gauger gives the operator what is known as a "run ticket," keeping a copy for himself. The pipe line company deducts the royalty due the owner of the property according to the terms of an agreement on file at the office, and the next day the producer may secure the cash for his petroleum at the market quotation for the day or hour of his sale at the nearest home office of the company,

NATURAL GAS.

BY F. H. OLIPHANT.

[F. H. Oliphant, geologist and mining engineer; born Uniontown, Pa., August 30, 1845; educated at J. R. Moore's academy at Morgantown, Pa.; employed two years as rodman for the Pennsylvania railroad; graduated from the Polytechnic college of Pennsylvania; served for many years as mining engineer for the Pennsylvania Gas Coal company and later as geologist for the Standard Oil company; has prepared the United States government annual reports on petroleum and natural gas since 1896 and is the recognized American authority on these mineral products.]

More than nine tenths of the natural gas output of the United States is produced and consumed in Pennsylvania, Indiana, Ohio, West Virginia, and New York. The value of natural gas in Pennsylvania in 1902 was only $913,910 less than that of the petroleum product of the state. In this state the largest part of the total value of the output of natural gas and petroleum was obtained. The combined value of petroleum and natural gas in 1902 amounted to $102,265,602, and ranked next to coal in the list of the values of the crude mineral products of the United States.

The principal elements in the composition of natural gas are carbon and hydrogen, which are combined, practically in the proportion of 75 per cent of carbon and 25 per cent of hydrogen forming CH_4, known as marsh gas or methane. This constitutes from 90 to 97 per cent of the different varieties of natural gas. The elements which go to make up the remainder are nitrogen, oxygen, carbonic acid, and hydrogen sulphide.

In the United States the principal sources of natural gas so far developed are along the west flank of the great Appalachian uplift, extending from western New York to central Kentucky; also on the crest of the great Cincinnati uplift, extending from central Kentucky northward into northwestern Ohio and central Indiana; and in southeastern Kansas. The areas thus briefly described include the main natural gas fields which, in 1902, produced 99.5 per cent of the entire output.

Natural gas is found also in limited quantities in California, Utah, Colorado, South Dakota, Missouri, Texas, and Louisiana, and a considerable amount has been produced in these states, although the pools lack the area, volume, and force of those

found in the Appalachian, Lima, Indiana, and Kansas fields.

East of the Mississippi river natural gas is found in the rock formation of the Paleozoic age, extending from the highest carboniferous strata down to the stratum that is lower than the Trenton limestone, while in the west and southwest the fields containing the gas are much more recent in the geological scale.

The reservoirs in which natural gas is usually found are composed of porous sandstone or limestone. In some cases a limited quantity of the gas has been found in shales, but this gas may be regarded as having gradually accumulated from the underlying rock formation. Almost invariably the large reservoirs have been developed in the strata on or near the crests of the anti-clinal or rock waves, while petroleum has been generally collected on the lower horizon; and frequently salt water is found at a still lower level. Sometimes, however, the gas fields are entirely isolated from the petroleum producing areas. There are three leading requisites necessary for the accumulation of natural gas in merchantable quantity. These are as follows:

First. An open or porous strata capable of storing the gas under pressure.

Second. A slate or shale covering of this porous strata to seal in the upper surface and the fractures of the strata saturated with natural gas.

Third. A sufficient flexure or relief of the strata to enable the separation of the salt water and the petroleum from the natural gas.

In order that the production of the gas may be profitable, the reservoirs must be packed with high pressure gas over a large area.

The original rock pressure has been found in very many instances to equal the hydrostatic weight of a column of water of a height equal to the distance from the point where the reservoir is pierced, to the surface. If it takes 2.3 feet of head of water to equal 1 pound to the square inch, or 43 pounds to the hundred feet, then a depth of 1,000 feet will equal 430 pounds to the square inch. This proportion of the depth to the pres-

sure has been proven to be quite near the actual results obtained.

The rock pressure and the output of gas wells are usually measured when the well is new and they are at their maximum. Even the longest life of a gas well is short, and the rock pressure decreases with every foot of natural gas taken out. It is not usual for wells having the greatest rock pressure to produce the greatest volume of natural gas, as an open pebble sand gives up its stored products more rapidly than a sand of closer texture; therefore the more open the texture of the strata, the shorter but more vigorous will probably be the life of the pool. Many pools that were most vigorous are almost entirely destitute of natural gas to-day. The gas in some of them has been so far removed by gas pumps that when they are opened the air flows into the vacuum in the porous strata once packed with high pressure gas. In many virgin fields, especially in the beds of streams, innumerable small vents and bleeders are often found, from which there is an escape of more or less natural gas in the form of bubbles. Against the hydrostatic pressure the bubbles find vent, and escape into the air. As the pressure decreases, the water usually climbs up toward the more elevated portion of the reservoir. These innumerable vents, during the ages that have passed, have acted as safety valves, and have allowed the escape of many millions of cubic feet of gas into the atmosphere. The contents of the known reservoirs are probably but a small fraction of the gas that has been dissipated in the air.

The search for and the production of petroleum, moreover, has caused a great loss of natural gas, since frequently the gas is found in the higher portion of the sand containing the petroleum, and is tapped before the petroleum is reached. In many cases the natural gas has been allowed to flow into the atmosphere and be wasted until the pressure was sufficiently exhausted to permit drilling to proceed.

In the most important fields of Pennsylvania, the original rock pressure varied from 375 to 1,000 pounds to the square inch, the average being 700 pounds. The output of some of the largest wells in the state ranged from 7,500,000 to 25,000,-

000 cubic feet in twenty four hours. A well producing about 1,000,000 cubic feet is considered a good well.

Some of the original wells in the Trenton field in Ohio gave large outputs when first opened. In the vicinity of Findlay and Bairdstown several very large wells were developed during the early history of the field, when the original rock pressure was about 450 pounds to the square inch, and several wells near the location named produced from 5,000,000 to 17,000,000 cubic feet in twenty four hours. Now there is an average of less than 20 pounds of pressure.

The more recently developed field in Knox county near Mt. Vernon, Ohio, contains a number of wells with an output of from 5,000,000 to 9,000,000 cubic feet in twenty four hours, the original rock pressure being about 680 pounds to the square inch. The gas in this field is found in the Clinton limestone, at a depth of about 1,850 feet.

Nearly all the natural gas produced in Indiana comes from the Trenton limestone. The wells at first were generally large producers, the output ranging from 1,000,000 to 10,000,000 cubic feet in twenty four hours. The original rock pressure was 325 pounds to the square inch; it is now less than 70 pounds, and even this light pressure is being rapidly diminished. There are localities where the original pressure is exhausted.

In West Virginia there are a number of powerful gas wells, the productive sands of which are deeply buried. The Big Moses well, on Indian creek, Tyler county, was in its day one of the very largest wells known, and for a few years delivered immense quantities of gas. The estimated output of this well when first opened was 35,000,000 cubic feet per day. Its life was only about two years, the nearness of petroleum deposits, which were soon after developed, allowing the escape of gas, and a great decline in pressure soon followed. There are numerous deep wells in West Virginia that have a rock pressure of over 1,000 pounds to the square inch; in some instances 1,500 pounds is recorded. A number of deposits of natural gas have been found in three or more distinct sands or horizons; the deepest wells measure about 3,200 feet. During the year 1900 a very large natural gas well was drilled near Goodhope, in the southern part of Harrison county. This originally had

an output of 45,000,000 cubic feet per day. There are numerous wells in this section, and in the western portion of Marion and Monongalia counties there are many with a capacity of from 1,000,000 to 15,000,000 cubic feet. Wetzel county also contains powerful gas wells with a depth of from 2,700 to 3,100 feet.

Southeastern Kansas has developed very fair natural gas wells of good endurance, the rock pressure of which is from 280 to 335 pounds to the square inch. Many of them have a volume of over 7,000,000 cubic feet per day, the depth being about 900 feet.

The existence of natural gas was discovered through the observation of bubbles in springs and streams, many of which would sustain a flame for an indefinite period. These springs and natural vents were known to the early pioneers, while for centuries before they had been known to the Indians, who viewed them with a certain amount of awe and veneration, since they cast a wierd light at night upon their camping grounds.

The white men drilling wells for salt brine were in many instances surprised by the outburst of imprisoned natural gas when their crude drills penetrated the sealed in reservoirs. These outbursts were often of sufficient violence to blow out the drilling tools, and in some instances they ignited and destroyed the primitive drilling plant.

In subsequent years the search for petroleum developed many pools of natural gas of high pressure, and in the early development of petroleum the finding of this gas was considered a dangerous and unwelcome discovery, although it was known and utilized in a few localities long before the first well was drilled for petroleum in 1859.

Natural gas has been developed almost entirely in the northeastern portion of the United States, there being only a few wells, comparatively, in the west and southwest portions. In Canada some has been found, a part of which has been consumed in the United States. Although natural gas is distributed largely over the entire globe, its development and use outside of the United States and Canada has been insignificant. There is at present a small consumption of natural gas in Eng-

land, in Sussex county. Holland makes use of it for the partial illumination of two small villages on the Zuyder Zee. Galicia, Roumania, Russia, India, Persia, and Japan use it in a limited way in the operation of petroleum wells and in refineries.

One of the most noted natural gas vents or springs located by the pioneers was on the northern bank of the Kanawha river, in West Virginia; this spring was visited in 1776 by General Washington, who was greatly impressed by the phenomenon. There was also a well known gas spring on the Big Sandy river 50 miles above its mouth; and numerous springs were known to exist on what has been called the St. Marys uplift, which extends 25 miles north from Burning Springs, on the Little Kanawha river. In the early history, wells drilled for salt water in the area extending from the Cumberland river, Ky., to above the mouth of the Kiskiminitas on the Allegheny river, very often developed large flows of natural gas. In some cases the flow of these wells was persistent, in other cases it was soon exhausted.

The earliest economic use of natural gas in this country was, in all probability, in 1821, when it was used in the lighting of the village of Fredonia, Chautauqua county, N. Y. On the banks of the Canadaway creek, on which Fredonia is situated, a well $1\frac{1}{2}$ inches in diameter was drilled to a depth of 27 feet, and from this was obtained a flow of natural gas sufficient for 30 burners, the light of each of which was considered to be equal to that of two good candles. Several years later, in 1825, a small gasometer was introduced, and afterwards a number of shallow wells were drilled, and from these more or less natural gas was secured. In 1871 a well developed a very large flow of natural gas when at the depth of 1,200 feet it pierced the Corniferous limestone.

A well dug for water at Findlay, Ohio, in 1838 produced large quantities of natural gas near the crest of the great Cincinnati uplift. The gas was collected and conveyed into the house of Mr. Daniel Foster, where it was utilized for nearly fifty years, until the regular development of the great Findlay gas field began in November, 1884.

In 1841 natural gas was developed in association with salt brine in a well drilled on the Kanawha river in West Virginia,

near where an original gas spring was located. The pressure was sufficient to force the salt brine up into a large hogshead where the salt and gas were separated. The salt brine was diverted into salt pans and the gas conducted to the furnaces underneath, where it was successfully used as fuel for the evaporation of the salt water.

More or less gas was developed on Oil creek, Pa., and in the surrounding section, by the wells drilled in the search for petroleum in the winter of 1859 and 1860. Some of these wells produced gas only, and others produced both gas and petroleum. For several years it was the common practice to conduct the gas to a safe distance and there consume it to get it out of the way. The high price of coal and wood and the extremely poor roads, finally induced some of the more venturesome to try to burn it under boilers. This experiment was so great a success that natural gas became a most efficient substitute for coal and wood. In its early application, however, numerous fires and explosions were caused by overpressure, because at that time no automatic method of regulating the pressure was known.

One of the first applications of natural gas for fuel purposes was in the year 1868, when a manufacturing company in Erie, Pa., drilled a well 600 feet deep into the Devonian shale. This well produced a considerable amount of gas when first opened, but the output gradually declined. Many wells that were sufficiently large to supply one or two dwellings were afterwards drilled in this locality.

Near Titusville, Pa., in 1872, thirteen years after the drilling of the first oil well, a powerful natural gas well was drilled on the Newton farm, $5\frac{1}{2}$ miles north of the town. The gas from this well was conveyed into the town by a 2-inch gas main which furnished 250 consumers with light and fuel. Afterwards the original line was reinforced by a second one $3\frac{1}{4}$ inches in diameter. The two lines maintained a steady pressure and a satisfactory supply. This was the first natural gas plant which supplied light and heat in any large and permanent quantity by methods and appliances similar to those in use to-day. It is looked upon as the beginning of the industry which has since assumed such large proportions.

During the year 1873 natural gas was successfully introduced for fuel and light at numerous localities in Venango, Butler, and Armstrong counties. It was also introduced at Leechburg, in Armstrong county, in the same year, the supply being obtained from an abandoned well drilled for oil in 1871, and was successfully applied in heating and puddling furnaces. Iron mills at Etna, near Pittsburg, Pa., were the first large mills to be supplied by a gas line of any considerable length. The supply was used for years. This line was built in 1875, and extended from the iron mills to the Harvey well, near Lardens mills in Butler county, a distance of 17 miles. This well was one of the largest known at that time.

By the close of 1883 several pipe lines were supplying the manufacturing establishments and the domestic service in Pittsburg, Pa., the supply being from the Murrysville pool, in Westmoreland county, which had been developed several years previously. In 1885 the Grapeville and the Speechley pools were first developed. The increase in its use was remarkable, and a number of pools in Washington, Butler, and Beaver counties were opened up and connected by pipe lines. In 1886 the gas field at Findlay, Ohio, began to be prominent. Afterwards a large field in Indiana was developed. The development of these large reservoirs of natural gas, hitherto unknown, seemed to impress the general public and many of the operators of natural gas fields with the idea that these reservoirs were practically inexhaustible. The fact that the quantity of gas withdrawn from any of the large fields by one or two wells decreases the volume and pressure very slowly caused a false impression as to the extent of the reservoirs. As the fields were developed, however, and many wells reached the gas reservoirs, the decline in the pressure became more rapid and noticeable.

In Pennsylvania, Ohio, and Indiana immense quantities of gas were consumed in wasteful and extravagant display, which in numerous instances almost turned night into day. This extravagance was not realized until the fields began to be seriously depleted. In the mills and factories the application of gas as a fuel was made in a wasteful and unscientific manner;

at least double the quantity of gas necessary to do a given amount of work was consumed.

In 1890 and 1891 many reforms tending to improve methods of storing, transporting, and consuming natural gas were inaugurated. The meter was introduced, which at once made it to the interest of the consumer to see that consumption was economical. The wells were controlled from the head office by telephones, so that when the supply was more than enough the gates at the wells were shut. The wells were watched more vigilantly, salt water was kept out with more care, and leaks and joints and all pipe connections were carefully examined and repaired. The use of large pipes by many of the gas companies began about this time, enabling them to send larger quantities to points of consumption at reduced pressure.

Natural gas is used principally as a source of light and heat in domestic service. It is employed extensively in industrial establishments for many purposes, notably in the manufacture of glass, in the generation of steam, puddling of iron, in roasting ores, in heating furnaces, and in the manufacture of steel, and it is also utilized as a source of power in the gas engine, in drilling and operating oil and gas wells, and in pumping oil. The heat value stored in natural gas is greater than that caused by any artificial combination of carbon and hydrogen, and is a perfect fuel as it issues from its original rock sealed reservoirs. No preparation is necessary for its combustion and no residue is left. It is not affected by ordinary temperature and it is easily distributed by pipes to points of consumption. It is a most economical source of light and power, and an ideal household fuel.

The illuminating properties of natural gas vary in different localities, because of the difference in the percentage of the heavier hydrocarbon, ethane (C_2H_6). All the natural gas found adjacent to petroleum fields has a larger proportion of ethane than the gas farther removed, and therefore the candlepower is considerably greater. Ordinary natural gas, if consumed with a common tip at the rate of 7 or 8 cubic feet per hour, will yield about 6 or 7 candlepower. In an ordinary Argand burner with chimney, it will give about 12 candlepower in consuming 5 to 6 cubic feet per hour. When natural gas

is consumed in contact with a mantle of alkaline earth (thoria, etc.), the result is the cheapest and best illuminant known. When the price of natural gas is 25 cents per 1,000 cubic feet, and 50 candlepower is obtained from a consumption of $2\frac{1}{2}$ cubic feet per hour, the cost per candlepower per hour is only 0.00125 of a cent.

There were 510,000 domestic consumers of natural gas during 1902, and it is estimated that in the western portions of New York and Pennsylvania, in central and western West Virginia, and in Ohio, Indiana, and Kansas, not less than 4,500,-000 persons received the benefit of natural gas used as a fuel and an illuminant. Over 8,000 manufacturing establishments were also supplied.

The introduction of natural gas into the household, for which it is eminently fitted, has been accomplished without personal inconvenience or loss of life, except in very rare cases. The risk from fire is less than when wood and coal are used. There have been some cases of asphyxiation when a stove has been burned in a room without a flue connection, as it has been found by experiment that combustion under these conditions is imperfect, especially so if the air in the room becomes more or less saturated with carbonic acid and the vapors of water, the result being the formation of poisonous carbonic oxide.

The calorific value of natural gas varies slightly in different localities, as the amounts of carbon and hydrogen vary. Those natural gases which contain the highest percentage of carbon give the best results in evaporating water. The standard used in measuring the evaporation of water is called the British Thermal Unit, and is the amount of heat necessary to raise one pound of pure water 1° F. at or near 39°, which is the temperature of the maximum density of water. The quantity of air necessary for the perfect combustion of natural gas varies from 10.4 to 10.8 parts of air to one part of natural gas. The products of combustion are water and carbonic acid.

The ultimate heat units in any fuel are not all available for the conversion of water into steam, a proportion being lost by radiation and in causing sufficient draft to supply the fresh air that is required to keep up the combustion. A number of

tests have fully demonstrated that when ordinary care is taken in burning natural gas under boilers in actual service, 1 cubic foot of natural gas will do the work equivalent to the evaporation of one pound of water at and above 212° F. Since 20 cubic feet of ordinary natural gas weigh one pound, one pound of natural gas will evaporate 20 pounds of water, while, under similar conditions, one pound of petroleum will evaporate only 16 pounds of water, and one pound of good coal will evaporate but 10 pounds of water; therefore 10 cubic feet of gas is equal to one pound of coal, or 20,000 cubic feet will equal one ton of coal.

Only two articles have been made directly from natural gas; they are lampblack and gas coke. Lampblack is still made, but gas coke ceased to become a product when natural gas as a fuel was consumed in an economical manner. In isolated districts, where it is difficult to convey the natural gas to market, numerous wells have been made profitable by the conversion of the gas into lampblack. The process is extremely wasteful, as the amount of carbon actually secured is probably not more than one twentieth of the carbon contained in the gas consumed. In the manufacture of lampblack or carbon black a great number of small jets are made to impinge upon a pipe, through which there is a circulation of water to keep it cold. The carbon is deposited on the pipes in very thin films and accumulates very slowly. Automatic scrapers and brushes are arranged to collect the deposit, so that the flames can have the clean, cold surface of the pipes upon which to deposit a fresh supply. The lampblack thus secured is said to be the very finest, and is used extensively at home and abroad.

Gas coke is a product of the imperfect combustion of natural gas when the unconsumed portion is highly heated. Under such condition the gas is decomposed and pure carbon is deposited. Generally the deposit was obtained from the fire boxes of the heating furnaces used in the manufacture of wrought iron, and found a ready sale for use in the manufacture of electric light carbons. It is similar in appearance to the coke formed from coal, and has a metallic ring when struck with a hammer.

The pressure in most of the original fields at first was ample

to convey large quantities of gas a number of miles through medium sized pipes. In after years a gradual reduction in the pressure made it necessary to install powerful compressing machinery. At first gas was used in the generation of steam as a motive power; afterwards the most successful and economical compressors were those in which gas was exploded directly in the cylinder.

Many of these compressor plants installed by the natural gas companies are models of the highest mechanical efficiency, some of the individual compressors developing as much as 2,000 horsepower and weighing from 250 to 500 tons. The more recent ones are so constructed as to use natural gas engines instead of steam engines for motive power. By the operation of compressors with the gas engine there is a saving of from 40 to 50 per cent in the amount of gas used, as compared with that consumed under boilers supplying double expansion engines. One of the first gas compressor plants using natural gas as a motive power is in use at Halsey, McKean county, Pa. This plant consists of four horizontal gas cylinders, in which natural gas is exploded, each having a diameter of 25 inches and a stroke of 4 feet. These cylinders are set tandem, two on each side of the main shaft, which carries two 13-foot fly wheels and operates four compressor cylinders. Two of these cylinders are high stage compressors, and two are low stage compressors, the former being 15 inches in diameter and the latter 31 inches in diameter; the stroke is 2 feet. The main dimensions are: Length, 75 feet, and breadth at fly wheel, 18 feet. In this engine one horsepower per hour is produced by the consumption of 9 cubic feet of natural gas.

Since the first successful use of the natural gas engine its application has been rapid as well as eminently successful; wherever natural gas could be secured this engine has been installed, and has fully demonstrated its economy and reliability. One of its greatest triumphs is that it dispenses with the costly and extravagant boiler.

Its merits are fully demonstrated in its application to the pumping of petroleum wells and the operation of the smaller force pumps used in the transportation of the petroleum. Its general introduction into the petroleum producing fields

has enabled the operator to pump economically small wells that otherwise could not be operated, and it has also enabled him to handle large quantities of water where petroleum must be secured at a small outlay. Petroleum wells are often pumped in clusters of from 5 to 25, the number varying according to the depth and other conditions. Where the wells are comparatively shallow, and not too far apart, they can be pumped readily and with small loss by means of rods operated by steam or gas engines. Formerly deep wells were operated by a single boiler in or near the center of a cluster of from 4 to 6 wells, each of which had a steam engine connected with steam pipes radiating from this boiler. The loss by condensation when this method was used was very great.

The gas engine has in many instances replaced the steam engine, the change often being effected by the removal of the steam cylinder and the substitution of a gas cylinder. The boiler is dispensed with. The gas engine will run unattended for hours, as it is only necessary that it be kept lubricated. The steam engines usually employed in petroleum operations are generally not well cared for, so that the steam used for the work accomplished is often extravagant. In ordinary practice the internal combustion engine, of which the natural gas engine is a type, is most economical, and equals in effectiveness the triple expansion condensing engine. When the natural gas engine is operated in the most economical manner, there is a saving of nearly 50 per cent in fuel over that required to be consumed under boilers to operate high duty steam engines, and a saving of 90 per cent over the consumption required for the ordinary steam engine.

Almost the entire production of natural gas is distributed to the consumers by wrought iron pipes, which vary from 1 inch to 20 inches in diameter. There are also in use a number of miles of riveted wrought iron pipes of a diameter of 3 feet. Lately many long lines have been constructed of pipe 18 and 20 inches in diameter. The pressure at the field end of these lines is in some instances as high as 400 pounds to the square inch, but it is usually from 100 to 200 pounds. Where the natural well pressure is not sufficient, it is increased by large compressors, before described.

Wrought iron pipes 6 inches and less in diameter are usually connected by collars with threaded joints. Recently the joints for the larger diameters have been made of sleeves of a larger diameter, between which and the pipe rubber packing is forced by flanges drawn together by bolts. This variety of joint is satisfactory in every way, and has a number of advantages over the screw couplings for larger diameters. It overcomes the trouble due to the expansion and contraction of the pipe line without a resort to fine bends; it enables the pipe to swing more or less; it adjusts itself to the inequalities of the surface; it cheapens the first cost, because no threads have to be cut; it is not so easily injured in transportation, and it is efficient in preventing disintegration by electrolysis in localities where electric roads are operated. Usually the main line pressure is reduced near the city or town line to a pressure of from 20 to 50 pounds, and the gas is fed into an intermediate system of pipes supplying the regulators that deliver the natural gas into the mains from which the consumers are supplied.

In the cities and towns there are two methods of distribution. The more common system is called the low pressure system, and usually carries a pressure of from $3\frac{1}{2}$ to 7 ounces to the square inch. This system consists of a series of pipes from 2 to 12 inches in diameter laid in the street at a depth of from $2\frac{1}{2}$ to 3 feet, the largest sizes being placed in the localities of the greatest consumption. To these pipes are connected the service pipes, which are usually from 1 to $1\frac{1}{2}$ inches in diameter, and lead into the consumers' houses. Between the high pressure lines and the low, automatic regulators are placed, adjusted by weights and diaphragms, in such a manner that the pressure remains almost constant, even when more or less natural gas is conveyed from the high to the low pressure. A series of liquid seals are used in connection with most of the regulators, which prevent any pressure over 16 ounces on the low side from getting into the dwellings; the liquid seals will blow out when such pressure is reached.

Another system is that of placing a reducing valve inside or near each house, this valve being connected with a smaller pipe conveying a higher pressure which is reduced by an individual regulator to a pressure of from 4 to 6 ounces. The

points of consumption are in many instances from 100 to 250 miles distant from the place of production.

The total length of pipes of all sizes from 2 inches up to 36 inches in diameter in use in the United States for conveying natural gas at the close of 1902 was 131,859,636 feet. This is equal to 24,973.41 miles—enough to more than girdle the earth at the equator.

Natural gas is usually sold to the consumer by the cubic foot, at a standard pressure of 4 ounces to the square inch, or 36 pounds to the square foot, at a temperature of 60° F. In many instances it is convenient to dispose of the gas to consumers at higher pressures, and then it is necessary to construct meters of proportional strength. The mean pressure of the atmosphere for the elevation at which most of the natural gas is sold is assumed to be 14.4 pounds to the square inch.

ASPHALTUM AND BITUMINOUS ROCK.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York city in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

Asphaltum is the name applied to different forms of bitumen. Its composition varies, and it is known by many other names, bestowed on account of some special characteristics resulting from its composition or the locality from which it has been obtained. The most common of these names are: Natural mineral pitch, Jews' pitch, Trinidad asphalt, Cuban asphalt, Dead sea bitumen, manjak, maltha, brea, chapapote, elaterite, wurtzilite, nigrite, gilsonite, grahamite, and uintaite.

Asphaltum has been an article of commerce from remote antiquity, the supply having been obtained from the deposits near the Dead sea, where the material floated on the surface or was washed ashore by the waves, the product being known to the Arabs by the name of Hajar Mousa, or Moses's stone.

In Germany asphaltum was known as early as 1626 under the name of harzerde (pitch earth), which was described in 1692 by Doctor Amiest as asphaltum. Bituminous limestone is mentioned by Doctor Erynis in several publications prior to 1721. The deposits at Seyssel, France, were discovered in 1802, and the asphaltum interests of France and Switzerland were united in 1832 by Count de Sassenay.

Asphaltum ranges in form from the liquid maltha to the hard, solid glance pitch, which gradually merges into asphaltic coal. The specific gravity of pure asphaltum ranges from 1 to 1.3 and the hardness from 2 to 3. The solid varieties

have a black or dark brown color and a peculiar characteristic pitchy odor when rubbed.

Asphaltum breaks with a more or less splintery fracture and does not soil the fingers. It is very brittle at low temperatures, but upon being warmed, although it remains sufficiently hard to be broken by a sharp blow, at the same time it yields to a steady pressure or tread. Asphaltums differ much in their properties, and all do not possess the binding power so necessary for a lasting pavement; they shade by insensible gradations into brittle asphaltic coals. The melting point of asphaltum is usually low. It is very inflammable, burns with a yellow, smoky flame, and when pure leaves very little if any residue. It is insoluble in water, slightly soluble in alcohol and fixed and essential oils, and readily soluble for the greater part in ether, oil of turpentine, naphtha, and carbon bisulphide. With benzole it forms a solution of an intense black color, used as a varnish. When subjected to destructive distillation, asphaltum is decomposed into a distillate of oils and a tarry residue which becomes solid when cold.

The chemical composition of asphaltum is so complex that elementary analyses throw little light on the subject. It still remains an open question whether important groups of definite and characteristic hydrocarbons can be separated and recognized.

Many chemical analyses of asphaltum from various localities have been published from time to time which, however, are of scientific value only.

Means other than chemical analysis are generally used to ascertain the commercial value of asphaltum. The first of these is a solubility test of the sample dried at 212° F. in various solvents, as carbon bisulphide, alcohol, turpentine, ether, petroleum, naphtha, etc. Distillation is often used and the losses at various temperatures are recorded. The quantity and quality of mechanical impurities (water, clay, earthy matter) contained in the sample are also determined; finally, the best test of its applicability for pavement purposes is its viscosity at various temperatures. In some cases the value of an asphaltum for use in pavement construction is determined by an actual trial.

The substances classed as bitumens are hydrocarbon compounds, the more important of which, arranged in the order of their specific gravities at 70° F., are divided into six groups:

1. Natural gas.
2. Natural naphtha.
3. Petroleum, or natural oil.
4. Maltha, or soft, sticky bitumen.
5. Asphaltum, or stiff, sticky bitumen.
6. Glance pitch, or dry, brittle bitumen (often called gilsonite).

In addition to the substances comprising the above list, there are other bitumens of chemical interest only which possess no commercial value.

In commerce there are four chief classes into which asphaltum is divided: (1) The natural liquid form, called liquid asphaltum or maltha; (2) asphaltum mixed with more or less vegetable and earthy matter, which yields, by the removal of the mechanically contained impurities, the product called hard, refined, or gum asphaltum; (3) asphaltum contained in sand or sandstone, called bituminous sandstone; (4) asphaltum contained in limestone, called bituminous limestone.

In addition to the natural products given in the above list mention should be made of by-product asphaltum, which is obtained in the refining of crude petroleum having an asphaltic base to yield commercial illuminating and lubricating oils. There is no strict line of demarcation between oils classed as petroleum oils and those considered as asphaltum oils.

The term bituminous rock is applied to both sandstones and limestones impregnated with asphaltum. Bituminous rock is sold and shipped without previous refining, and is consumed chiefly for street pavements, being generally mixed with other ingredients at the place of use. An inconsiderable proportion, however, is treated for its asphaltic content, the product being sold as refined or gum asphaltum.

Asphaltic or bituminous limestone is a natural compound of asphaltum and limestone, at times containing, in addition, other bituminous substances, sand, and sulphur bearing compounds. The quantity of asphaltum present varies in different deposits, and even in different portions of the same

deposit, up to 20 per cent. The grain of asphaltic limestone is extremely fine, and under the microscope each grain appears completely coated with asphaltum. It is this property which renders the natural product of greater value than an artificial mixture of asphaltum, fine sand, and pulverized limestone.

The formation of natural asphaltum is attributed by some geologists to the slow decay and decomposition of vegetable matter whereby the contained hydrocarbons have been distilled and subsequently condensed in the adjoining rocks, the product thus collected forming asphaltum deposits. The formation of artificial asphaltum in the manufacture of gas by the distillation of coal in a retort is quoted as proof of this theory. In this process a considerable portion of tarry matter passes over and is collected during the distillation which yields, by a second distillation, naphtha and other volatile products, leaving as a residue in the retort a tarry substance possessing the properties of asphalt.

Other geologists claim that asphaltum is the result of the decomposition of certain petroleums under the influence of heat, accompanied by polymeric changes not fully understood, whereby the more volatile constituents of the oil are expelled, leaving the residue in the form of solid asphaltum.

Asphaltum is seldom found native or pure, the principal known deposits containing it in admixture with other materials, chiefly earthy matter, sand, or sandstone and limestone. It occurs disseminated throughout many crystalline rocks, and is not restricted to any one geologic formation. It is not known, however, in the Archæan age. In many cases it has been deprived of volatile matter, which has caused it to resemble anthracite. It occurs also in veins that have been evidently injected into fissures, while in a plastic condition, exemplified by the minerals albertite and grahamite. It exists as a liquid in bituminous limestones and sandstones, from which it oozes, constituting the so called tar springs.

The most important of the liquid asphalt deposits are found in southern California, of which the Las Conchas mine on the ocean near Carpentaria has been operated successfully.

The maltha impregnates a clean quaternary beach sand of from 20 to 30 feet in thickness, overlying a bituminous shale from which the liquid asphalt exudes. The crude sand containing about 20 per cent of bitumen is refined to a product of 95 per cent bitumen content. The refined liquid is used to soften solid asphaltum and to coat wood and masonry for protection against the penetration of moisture.

Asphaltum is found in beds resulting from the oxidation either of mineral tar or, primarily, petroleum. This class includes the immense deposits at Tamaulipas and Moloacan, Mexico. There are many and diversified occurrences of asphaltum in Europe, the chief deposits being the bituminous limestones at Seyssel, France; at Val de Travers, in Neuchatel, Switzerland; in the Dinaric Alps, bordering the eastern coast of the Adriatic sea; and at Ragusa, Italy. In Asia it occurs at many localities in Syria, around the Dead sea, the source of the early supply of asphaltum.

The largest producing asphaltum deposit of the world is at Pitch lake, on the island of Trinidad, where the asphaltum occurs in the form of a basin shaped deposit 18 feet thick at the edges and 80 feet thick at the middle, with an estimated content of 6,000,000 tons of asphaltum. The deposit is supposed to be supported by water, and while solid enough to admit of the passage of wagon and horse, it has a slow movement which tends to draw in the tramway used to convey the excavated material to the shore of the lake, unless properly supported by branches of trees. In fact, excavations of a depth of 20 feet have become filled in six months. The asphaltum is broken from the mass by means of picks, before daylight while the material is brittle; it is then loaded on cars and conveyed by the tramway to the shore, from whence it is carried to the pier, 3,500 feet distant, by an aerial wire rope conveyor and dumped directly into the holds of the vessels. On the voyage it becomes agglomerated into a solid mass, which must be again broken up by pick in order to remove it from the vessel. The product is roughly refined by heating in tanks and straining the liquefied material through a screen for the separation of roots and other vegetable matter with which it is con-

taminated. There is a similar lake deposit near San Timolis, in Venezuela, the product being known commercially as Bermudez asphaltum.

At the present time the chief producing localities are Trinidad, Dalmatia, Syria, Cuba, and the Seyssel, and Val de Travers deposits of bituminous limestones; local supplies of more or less value are obtained from other localities.

An asphaltum property near Pike City, Pike county, Ark., consists of a stratum of sand from 6 to 12 feet thick, containing various proportions of semi-fluid asphaltum. The product is obtained by sinking shallow pits, into which the material oozes from the bed. Borings have proved that the asphaltum beds extend over an area of several acres. A pit 100 feet in diameter has been dug, and a spur has been built to the railroad a half mile distant. A special feature of some portions of the bed is the occurrence of limestone with the sandstone, which yields a product available for paving purposes without the addition of other material.

The utilization of the asphaltum deposits in this state is solely a matter of cost of transportation. The average grade product should easily control the markets of Little Rock, Texarkana, and Fort Smith, and the higher grade material should compete advantageously with other asphaltum in cities as far distant as Memphis and St. Louis. It is also probable that pure asphaltum could be extracted from the asphaltic sandstone at a profit greater than that obtained by the crude product.

On the Sisquoc ranch, Santa Barbara county, Calif., the principal asphaltum property is the mesa deposit, 1,300 by 5,000 feet in area and of a reported minimum depth of 125 feet, which is estimated to contain 25,000,000 tons of bituminous rock, equivalent to 5,000,000 tons of asphaltum. The rock is mined, elevated bv an electric crane, and shipped in steel cars to the refinery works on the mountain side, where gravity is utilized to move the materials. The crude rock is crushed by steel rolls and heated in revolving steel jacketed drums, and as it becomes softened by heat it is treated with gasoline until thoroughly saturated. It is then passed into a

series of agitating drums, which separate the solution containing the asphaltum from the tailings; the solution flows by gravity to the stills, and the gasoline is removed and recovered for repeated use. The residue in the still, consisting of asphaltum of 99 per cent purity, is cooled and barreled for shipment.

The product of the companies operating these mines is chiefly a bituminous sandstone, largely utilized for paving purposes on the Pacific coast, where, owing to the simple method of its preparation and the cheap water freight rates, it competes successfully with other asphaltum paving mixtures. There is no production of asphaltic limestone in California worthy of mention. In addition to the producers of asphaltum from natural rock in this state, a large number of crude petroleum refineries have been established, which furnish a considerable quantity of by-product asphaltum obtained from the crude petroleum oils of California. By-product asphaltum possesses similar properties to that obtained from the rock deposits, and replaces it to a considerable extent in paving and other uses.

The known asphaltum deposits in Indian Territory are almost entirely within the reservation of the Chickasaw nation. Development work has been started at Ravia, Dougherty, and Tar Springs, and at the two former localities soft asphaltic sands and a bituminous limestone have been mined, and at the last named place asphaltic sandstone is produced. Grahamite is mined near Tar Springs, the product being hauled to Comanche, 18 miles distant. Considerable prospecting by drills has been accomplished in the vicinity of Tar Springs, and other deposits of asphaltic sands have been found below the surface deposit, separated therefrom by beds of red and blue clay and shale. The thickness of the asphaltic sand beds varies from 3 to 20 feet, while the clay and the shale strata range from 5 to 40 feet in thickness. The lower limit of the asphaltic sand has been found at a depth of 600 feet from the surface. The present supply of asphaltum is obtained by open cut working. The sandstone capping is removed by drilling and blasting, and the soft asphaltic sands are broken up by blasting and removed by plows and scrapers to the re-

finery, where the sterile sand is segregated by mechanical concentration with hot water. The asphaltic material rises to the surface and passes to the reducers, where it is brought to the proper consistency by the application of heat and subsequently strained and barreled for shipment. The products vary with the demands of the market, and range from a semiliquid on the one hand to a hard and brittle form on the other. Very little of the latter is made, however, on account of the large amount of time and fuel required to produce it.

The principal bituminous sandstone deposits in Kentucky are in Logan, Warren, Edmonson, Butler, Grayson, and Breckinridge counties, occupying an area of 20 by 50 miles in the central part of the state. The deposits are in fine grained sandstone of the subcarboniferous formation, and from geological evidence the asphaltum represents the residual matter from preexisting beds of petroleum. The numerous deposits in Grayson and Edmonson counties vary both in richness and magnitude, the range in the thickness of the beds being from 2 to 20 feet. But few of these deposits, however, are of commercial value. The richer deposits lie between strata of black rock from 1 to 2 feet thick, and the intervening asphaltum ledge varies in thickness from 3 to 15 feet and contains from 5 to 15 per cent of bituminous matter; below 4 per cent asphaltum content the material merges into black rock.

Up to the present time only those deposits lying conveniently near railroad or river have been developed, and of such only those have been developed, and of such only those have been worked, which offer the least difficulty in the way of uncovering. No tunneling or drifting has yet been attempted. At Bowling Green there is a 200 ton refining plant, equipped with corrugated rolls. The moisture in the material as it comes from the crushers is expelled by means of steam jets.

A property 4 miles northeast of Russellville, Logan county, has been developed quite extensively, the quarry face showing a 17 foot asphaltum ledge. The plant of this company includes a 250 ton gyratory crusher and plain 14 by 18 inch rolls. Quarries, mill, and tipple are connected by $1\frac{1}{2}$ miles of narrow gauge track, and at the end of the year the rolling stock equipment consisted of 45 cars. At Louisville, the operating com-

pany has installed a plant for mixing and preparing asphaltum for street paving work, which has a daily capacity of preparing material to cover an area of 18,000 square feet.

An asphaltum company near Garfield, Breckinridge county, has a 100 ton plant. The asphaltic rock is broken in two sets of beaters revolving about horizontal shafts, the first making 600 and the second 1,200 revolutions per minute. The coarsely broken material from the first beater is passed to a 2-inch screen, the oversize being returned for a second treatment. The material passing through is treated in the second beater, which delivers to a screen. Material exceeding one-sixteenth of an inch in size is returned to the second beater for another treatment.

In recent years a small quantity of asphaltic limestone has been produced from deposits in the eastern part of Utah, nearly the entire output being consumed in the local markets. The chief asphaltum product, however, is gilsonite (also called grahamite), which is mined about 60 miles from Vernal, Uinta county. Gilsonite is a very high grade material, of especial value for manufacture into varnishes, lacquers, paints, and similar products. On account of the high price it commands, the product can stand a long distance freight rate to chemical works.

The principal use for asphaltum is in the construction of pavements. In addition, a considerable quantity is consumed for the manufacture of special varnishes; for waterproofing buildings and other objects as a protection against dampness; for coating vessels, as a protection against the teredo, or ship-boring worm; as an enamel for iron objects; for roofing purposes in the form of asphaltum or tar paper; for electric current insulation; and as an ingredient of cement.

Asphaltum sidewalks were first used in Paris in 1838, and to-day they extend to a distance exceeding in the aggregate 1,200 miles. The introduction of asphaltum pavements in the principal cities of the world is given by J. W. Howard in the following chronological order: Paris, 1854; London, 1869; Budapest, 1871; Dresden, 1872; Hamburg, 1872; Berlin, 1873; followed shortly afterwards by Brussels, Geneva, Leipzig, Frankfort, and others. In the United States a so called tar poul-

tice pavement, composed of coal or gas tar, sand, etc., was laid in several cities during the period from 1870 to 1873, and in 1871 to 1873 successful experiments were carried out with an artifical asphaltic sandstone pavement in New York city, and in Newark, N. J.   In 1878 a pavement composed of Trinidad asphaltum, sand, and powdered limestone was successfully introduced in Washington, D. C., and has since been the standard pavement of that city.   At the present time more than a hundred of the principal cities of the United States have adopted some form of asphaltum pavement.

In making asphaltum pavement the general procedure is to grade the street to be paved, roll it with a steam roller, and then cover it with a layer of cement concrete 5 or 6 inches thick; or in case the street is macadamized or paved with stone blocks, the concrete is unnecessary.   In the latter cases a thin layer of asphaltum concrete from 1 to 1.5 inches thick is laid directly upon the old surface.   The foundation having been thus prepared, the asphaltum paving mixture, called the wearing surface, is then spread over it with heated rakes to the desired thickness, which varies from 1.5 to 2.5 inches, depending upon the traffic to pass over it.

The ordinary Trinidad asphaltum paving mixture is made by adding and thoroughly mixing with hot refined asphalt about 15 per cent of its weight of residuum oil, the mixture serving to cement together the sand and powdered limestone which enter into the paving mixture.   The proportions of the ingredients vary according to their physical and chemical quality, as well as to the climate in which the pavement is to be used, hot climates requiring less cement than cold.   A typical pavement is composed of from 15 to 18 per cent of asphaltic cement, from 70 to 83 per cent of sand, and from 5 to 15 per cent of limestone.

For use in making pavements, the mined asphaltic limestone is crushed into pieces not exceeding 2 inches in diameter, and then reduced to about 10-mesh size in a ball or centrifugal pulverizer.   The fine material is heated to 275° F. in heaters, spread over the prepared roadbed, and compressed by heated rammers, or otherwise, until it is of a thickness of from 2 to 2.5 inches.   This form of pavement is not popular

in places subject to fogs, rains, and low temperatures, for the reason that it becomes polished and slippery when wet, or dry in cold weather. In Paris and Berlin large supplies of sand are kept near the streets paved with asphaltic limestone for use during fog, slight rain, or snow.

Pavements made with Trinidad or other asphaltum in which sand, in proportions up to 80 per cent, is the chief ingredient, do not become slippery except when covered with ice; the sand makes them gritty and not susceptible to polish.

For the manufacture of black varnish, used chiefly for coating ironwork, pure asphaltum is dissolved in benzole or liquids containing benzole. The asphaltum from Syria is used for this purpose. By covering hot iron with asphaltum varnish, the volatile ingredients of the latter are driven off, leaving a residual coating in the form of a smooth and polished enamel.

For insulating and cementing purposes asphaltum forms a very important ingredient on account of its wonderfully adhesive quality.

For waterproofing foundations of brick or stone, asphaltum is dissolved in petroleum and laid in the form of a cement or mortar, forming a very durable waterproof coating.

For making cement, petroleum residue is added to asphaltum in order to render it plastic, and from 5 to 10 per cent of sharp sand is mixed with it, according to the purpose for which it is to be used.

For roofing purposes asphaltum is used to a very large extent in admixture with coal tar, pitch, or petroleum residue; the material being used to saturate two or three thicknesses of felt, which are finally compressed into one compact sheet. The tar or roofing felt is held in place by nails driven through tin disks, and the whole completely covered with cement similar in composition to that used in making the felt; while this is still soft, a covering of sharp sand, or screened gravel, is spread over the surface, forming a tight roof of great durability.

There are various methods used for the refining of asphaltum, depending on the nature of the crude material and the use to which it is to be applied. In general, with high grade

material, the treatment has for its object the removal of water, volatile hydrocarbons, and mechanically suspended mineral and vegetable matter, but with asphaltums to be used in pavement construction it is essential to allow the mineral matter to remain in the product, for the reason that the asphaltum in this case is to serve solely as a binding and waterproofing material. In fact, asphaltic rock of the proper composition is not refined before use, but merely crushed, heated and laid in place. The simplest method of extracting asphaltum from its compounds is by boiling in water, which causes the lighter asphaltum to rise to the surface, from whence it can be easily removed. Common salt or calcium chloride may be substituted for water in the treatment of material requiring a higher temperature or a heavier supporting liquid. In other cases asphaltum is extracted by means of a solvent, such as carbon bisulphide or naphtha, and obtained from the solution by heating in stills, which causes the volatile solvent to be distilled for repeated use and leaves the liquid asphaltum residue in a practically pure condition.

GYPSUM.

BY STORY B. LADD.

[Story B. Ladd, statistician, is one of the experts of the United States census bureau, in which capacity he has done important statistical work, including an investigation of the gypsum industry made by him for the twelfth census; he is the acknowledged authority on gypsum and its extraction and its products.]

Gypsum, a natural product, is calcium sulphate, of the chemical formula $CaSO_4.2H_2O$, containing 46.5 per cent of sulphuric acid, 32.6 per cent of lime, and 20.9 per cent of water. Anhydrite, a mineral like gypsum, but as its name indicates, containing no water, is composed of 58.8 per cent of sulphuric acid and 41.2 per cent of lime. This absorbs water and changes to gypsum. When gypsum is properly calcined it loses a part of the water of its composition and becomes plaster of Paris, the name originating from the great deposits of gypsum worked at Montmartre, a suburb of Paris. The transparent crystallized variety of gypsum is called selenite; its fine massive variety, alabaster; and its fibrous form, satin spar. A loose earthy gypsum found in Kansas and other points in the west is called gypsite.

Gypsum crystallizes in the monoclinic system, has a hardness of 2, and a specific gravity of 2.31. Its color is white, although sometimes red, green, blue, gray, or brown. When protected from the action of water it is extremely durable, as evidenced by the numerous monumental effigies, many centuries old, in European churches and elsewhere.

It is quite generally distributed and occurs in irregular and often in very extensive and massive deposits. A deposit of white crystalline gypsum at Netherfield, England, is more than 50 feet in thickness, and in the Thüringerwald, Germany, a great mass has been sunk through to a depth of 70 feet. The gypsum deposits of Onondaga county, N. Y., show in places a thickness of 60 feet. The snow-white alabaster found at Volterra, in Tuscany, Italy, is used extensively at Florence and Leghorn for works of art. It is white when newly broken and

on drying becomes even whiter on the surface. It is easily cut and turned and under proper treatment takes a fine polish and satin luster.

Gypsum deposits have been formed by direct deposition, and by the alteration of existing lime deposits. Most of the gypsum deposits of the world are considered to have been formed by the evaporation and concentration of sea water, although the calcium sulphate is not deposited until about 80 per cent of the water has been evaporated.

When such a body of water cut off from the ocean is evaporated, the calcium sulphate is deposited before the sodium chloride, the latter being thrown down only after the removal of 93 per cent of the water. With complete evaporation and deposition there would be, therefore, first a deposit of gypsum and then a heavy deposit of salt, though the evaporation may go far enough to deposit the gypsum, but not far enough to deposit the salt; or if the latter be deposited, it may be removed subsequently by solution. Gypsum deposits, therefore, are more widely spread than salt, but usually occur in thinner beds.

When sulphuric acid, liberated by the decomposition of pyrite, acts on calcium carbonate and converts it into calcium sulphate, there is generally a gradual transition from the lime.

Gypsum is deposited by some thermal springs, as in Iceland, where the sulphurous acids on becoming oxidized change to sulphuric acid, which converts the calcium carbonate into calcium sulphate, and this when evaporation takes place is deposited in fibrous and crystalline forms.

The theory of Dawson on the origin of gypsum at Plaister Cove, Nova Scotia, is as follows: First, there was an accumulation of numerous thin layers of limestone, either so rapidly or at such great depths that organic remains were not included in any but the upper layers. Second, there was an introduction of sulphuric acid, in solution or in vapor, which was a product of volcanic action. Then for a long time the acid waters acted upon the calcareous material without interruption from mechanical detritus, changing the calcium carbonate to calcium sulphate, and gypsum of good quality accumulated in considerable thickness.

Gypsum is widely distributed geologically, being found

in various formations ranging from the Silurian up to Tertiary. In New York extensive beds of gypsum are found in the Silurian formation; in Ohio and Michigan they occur in the Carboniferous; and in Iowa and Kansas they are Cretaceous. Gypsum is also widely distributed geographically. In the United States it is found in Arizona, California, Colorado, Iowa, Kansas, Michigan, Montana, Nevada, New Mexico, New York, Ohio, Oklahoma, Oregon, South Dakota, Texas, Utah, Virginia, and Wyoming, and is mined in all these states except Arizona, Missouri, and New Mexico. It is found in Arabia, Austria, Bohemia, Canada, Egypt, England, France, Germany, Italy, Norway, and Persia.

The use of gypsum was known at a very early period, for the Greeks were familiar with it, as shown by the writings of Theophrastus and Pliny. Gypsum in its ground, uncalcined state is used chiefly for land plaster, a fertilizer. In its calcined form, as plaster of Paris, it has extensive and varied uses.

Ground plaster has long been used as a fertilizer. Virgil wrote concerning the value of gypsum on cultivated lands. Benjamin Franklin called attention to the value of gypsum as a fertilizer for grass by sowing land plaster in a clover field, so as to form the sentence, "This has been plastered with gypsum," the letters showing by the height and color of the clover where gypsum had been sown.

The theories of the action of gypsum as a fertilizer have been many. Sir Humphry Davy and others before and after his time have regarded gypsum as a direct source of plant food. It is now thought that gypsum acts as a fertilizer in three ways, one mechanical and two chemical:

(1) The gypsum by mechanical action flocculates loose soils.

(2) Gypsum as pointed out by Storer has nearly one half its weight in oxygen and gives this up to many substances, and so may act upon nitrogenous and carboniferous substances in the soil.

(3) Gypsum decomposes the double silicates in the earth, setting free potash as a soluble silicate.

By this means the potash in solution reaches the roots of the plants. Soils with abundant potash do not need land

plaster, and soils with no potash compounds are not benefited in this respect by it.

The phenomena attendant upon the baking and hardening of plaster of Paris were first studied by Lavoisier. In the Comptes Rendus of February 17, 1765, appears the following: "After having removed the water of hydration from gypsum by heat, if it be presented to it again (this is commonly known as the mixing or tempering of plaster), it takes it back with avidity, and suddenly assumes a state of irregular crystallization; the small crystals which form become confused with each other, the result being a very hard mass." Lavoisier discovered that when plaster was baked at too high a temperature it lost its peculiar property of setting, and that when it was heated the water of crystallization was removed at two different stages, three fourths of it being much more easily removed than the remainder. Payen, in 1830, found that gypsum began to lose its water of crystallization at 115° C., and that the loss increased rapidly as the temperature rose. He concluded that a temperature of from 110° to 120° C. was the best for calcination, but that plaster of Paris could be made at a lower temperature, even as low as 80° C., if the burning were continued long enough. He found that gypsum was dehydrated if heated to about 250° C., and from 300° to 400° C. it lost completely the properties of hydration.

In the manufacture of plaster of Paris the gypsum rock is crushed and ground into a flour in a buhr mill, a roller mill, or a disintegrator. The ground gypsum is then passed into storage bins. In some mills the flour gypsum is conveyed to the bins by an air blast.

The calcining kettles are made of boiler steel and hold about 8 tons; the flame is carried around the sides by flues, so as to heat all parts. In charging, the ground gypsum is run slowly into the kettle, which is kept at a temperature of 212° F. or over; about an hour and a half is consumed in filling to a depth of 5 feet. The material is kept in motion by a mechanical stirrer, it being of the greatest importance that the partly calcined plaster shall not remain in contact with the heated iron. The slow filling tends to keep the heat constant or nearly so during the charging, and as the boiling increases the plaster

is occasionally thrown in waves out of the kettle. The heated material boils like thick cream, and runs almost like water. The boiling is, of course, due to the escape of the water of crystallization and the hygroscopic water that may be present. The boiling takes about three hours; a short time before completion, when the temperature reaches 270° F., there is a sudden setting down and the steam ceases to rise, marking the period of formation of the first hydrate. Soon the mass begins to boil again; after a certain time, quite accurately determined by the expert calciner, when a temperature of approximately 350° F. is reached, the charge is done, the discharge gate is opened, and the finished product runs out into a vault. The refilling of the kettle for the succeeding charge begins at once.

As plaster of Paris, when mixed with water, sets in from six to ten minutes, material is incorporated therewith, either during its manufacture or at the time of its preparation for use, to delay or hold back the set, in order that the cement plaster can be prepared in quantity and applied with uniform results. These compounds or admixtures are known as retarders or restrainers. In the early days of cement plaster, glue was added by the workman when he prepared the material for use; but now to secure uniform results, the retarder is, as a rule, incorporated with the plaster in the process of manufacture. Citric acid was used for a time, but this was expensive, and the results were often uneven. As magnesian limes set more slowly than calcareous limes, it was thought that the addition of magnesian limestone would serve as a retarder, but the use of this substance is said not to be a success. In the days of the Romans, blood was used to retard the set of plaster of Paris, and organic matter from slaughterhouse refuse (tankage, bones, hair, etc.) forms the base of many of the retarders now in use.

Any substance which, when added to the water with which calcined gypsum is mixed, or to the dry plaster, will keep the molecules apart or from too close contact will delay the crystallization and retard the setting. Such substances are dirt or organic matter not of a crystalline character. Insoluble material or carbonates of the alkaline earths will dilute the plaster so that it will not set as quickly as the unadulterated

plaster. Whether a retarder weakens the cement plaster or not is a disputed question among architects and plasterers, although it is conceded that the addition of too much foreign material reduces the strength of the mass of interlacing crystals. As a general rule the prolongation of the period of crystallization or set is determined by the quantity of retarder added to or incorporated with the plaster. Calcined plaster, which sets slowly, whether retarded or not, is known as cement plaster.

It is a well known fact that when a salt crystal is dropped into a supersaturated solution of a salt, as for instance sodium sulphate, the whole mass immediately crystallizes. Crystals, or even solid particles of foreign material, will hasten the crystallization. Hence, to make a quick-setting plaster, as for dental use, some other crystallizing salt, as alum or borax, is added, in small quantity, to the calcined gypsum. The result is that, after solution, the added salt has a tendency to crystallize, and thus starts the process in the dehydrated gypsum.

When calcined gypsum is steeped in a solution containing from 8 to 10 per cent of alum, and then dried and again burned with a dull red heat of uniform and constant temperature (Greenwood's process), a plaster is produced which after setting is very much harder than the ordinary plaster. Casts made of such plaster solidify gradually, but finally acquire a hardness similar to that of alabaster or marble, and present a translucent appearance resembling these substances. According to Landrin, this change in the plaster is not to be accounted for by the formation of double sulphates of lime and alkali, nor by the crystals of calcium sulphate being imbedded in alumina; but rather by the calcium carbonate in the plaster stone being converted by the alum into calcium sulphate. A liquid containing from 8 to 10 per cent of sulphuric acid acts in a similar manner.

Keene's hard cement is produced by impregnating plaster of Paris with a solution of 1 part of borax and 1 part of cream of tartar in 18 parts of water, drying and burning at a low red heat for six hours. Borax alone serves the purpose. The plaster hardens more slowly as the solution is more concentrated.

Silicated plaster is formed by sponging the surface of plaster casts with a solution formed by first adding whey, free from fatty matter, to a potash lye solution made by adding 1 part of potash to 5 parts of water, and afterwards mixing 4 parts of this with a simple solution of potassium silicate.

Stearin melted at not too high a temperature has been employed as a bath in which plaster casts are immersed.

Landrin found that lime had great influence on plasters. By mixing lime with the plaster in different proportions, not to exceed 10 per cent, he obtained plaster which set regularly, became very hard, and took a high polish.

A large number of patents have been issued for retarding compounds and admixtures, and for prepared plasters, as well as for processes of manufacture and for hardening gypsum, and a digest of the same will be found in an appendix. There have also been issued some 280 or more patents for improvements in the arts involving the use of gypsum or plaster of Paris in the manufacture of artificial stone, wall and roofing cements, pavements, crayons, blackboards, heat insulating composition, etc.

BORAX.

BY JOSEPH STRUTHERS.

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The occurrence of borax in the United States was discovered in California by Dr. John A. Veatch, January 8, 1856. Having boiled a small quantity of water from Lick Spring (then known as Tuscan Spring), Doctor Veatch noticed that, as the water cooled, crystals formed and adhered to the sides of the vessel. These crystals proved later to be sodium biborate, or borax. Shortly afterwards Doctor Veatch found small quantities of borax at the mouth of the Pitt river, in Shasta county, and traces of this salt in numerous springs in the Coast Range mountains; but it was not until September, 1856, that he discovered the extensive marsh deposits on the eastern side of Clear Lake, in Lake county, which subsequently furnished a large share of the borax produced in the United States.

The year 1864 witnessed the beginning of the borax industry in this country. In that year 12 short tons (24,304 pounds) of borax were obtained by evaporating the saline waters from Borax lake, adjacent to and connected with Clear lake, in Lake county, 80 miles north of San Francisco. Later the waters of the lake were enriched by the addition of crystalline borax collected from the alkaline marshes surrounding the lake.

Until the early seventies, the output of borax in California was obtained solely from the waters of Clear lake and other lakes in the state, but after that time the discovery of large quantities of pure borax in many of the alkaline marshes in

eastern California and western Nevada, caused the abandonment of the lake refineries and the erection of new plants, notably near Columbus, Nev.; at Searles marsh in th Amargosa valley; and at the mouth of Furnace creek in Death valley, California. Despite the difficulty and great cost of transporting the refined product by teams 100 miles to the railroad, the refineries continued in successful operation for several years, until the relatively large increase in the domestic output, together with the increased imports from Italy, so reduced the price that the working of the marsh deposits became no longer profitable and the refineries were closed down. About the year 1890 it was found that the borax crust on many of the marshes had been formed by the leaching of beds of calcium borate (borate of lime) in the Tertiary lake sediments in that region. Owing to the large extent of these bedded deposits, which possessed also the double advantage of containing a purer grade of mineral and of being more easily accessible than the marsh deposits, the borax industry as it existed at that time was revolutionized. A mine was started on a bedded deposit of from 6 to 10 feet in thickness at Borate, 12 miles northeast of Daggett, Cal., in San Bernardino county, and a refining plant was erected by the Pacific Coast Borax company. This company was organized in 1888, and at the present time is the chief producer of borax in the United States, as well as the producer of a large part of the output of boric acid. The ore at Borate consists of colemanite (a calcium borate mineral) in large masses more or less connected by stringers and bands in a bedded deposit of from 5 to 30 feet in thickness, interstratified in lake sediments. The great value of this deposit led to extensive prospecting in other parts of the state, which has resulted in the discovery in Death valley of enormous quantities of colemanite reported to exceed greatly in value the deposit at Borate. Both at Borate and in Death valley the deposits are of similar occurrence, being contained in a regular stratum interbedded with semi-indurated sands and clays which comprise the bulk of the strata. These beds are regarded as of Tertiary age, and are supposed to have been deposited from inclosed bodies of water. Large plants for the concentration and refining of the crude ore have been erected in California:

At Alameda, near San Francisco, at Marion, and at Daggett. The largest borax refinery, however, is at Bayonne, New Jersey.

There are four companies engaged in the borax industry in California—the Pacific Coast Borax company, the American Borax company, the Western Borax works, and the Frazier Borate Mining company. The Pacific Coast Borax company continues to supply a sufficient quantity of borax to satisfy the requirements of the market; and apart from its operations at Borate, prospecting work for other colemanite deposits has been carried on in Death valley and much additional property has been acquired. The deposits in Amargosa valley were carefully examined and large sample lots of ore were transported by traction engines to Manville, 100 miles distant, and thence by rail to the refinery for testing the quality, in order to determine the value of the property.

The plant of the American Borax company at Daggett has been greatly extended by the addition of two 20,000 gallon tanks or digesters for the treatment of the crude material from the adjacent mud deposits by the sulphuric acid process. The enlargement of this plant has greatly increased the output of boric acid concentrates, and the results have been so satisfactory that a further extension of the plant at Daggett is contemplated. A new refinery is in course of erection at Pittsburg, to which will be shipped the concentrates from Daggett for the final refining.

The mines of the Western Borax works are located in Inyo county, and those of the Frazier Borate Mining company in San Bernardino county.

Apart from the output of the above named concerns, a small quantity of borax has been obtained from the marsh deposits in California and Nevada, but the total amount produced from these scattered sources has been of so little comparative importance that the borax market was in no way affected. During the past few years Oregon has contributed to the domestic supply a small quantity of borax from the marsh deposits in Harney county. The output has averaged about 400 tons annually. The chief borax producer in this state is the Rose Valley Borax company, controlling 2,000

acres of rich marsh land near Lake Alvord in the southern part of Harney county. The total area of the deposit, which is south of the lake, aggregates approximately 10,000 acres. The ground is level and treeless, and is incrusted with a layer several inches thick containing in addition to sodium borate numerous other salts of sodium. During the long summer months the loose surface deposit is shoveled into small heaps, and is subsequently replaced with a second incrustation within a comparatively short period of time. The stock of crude material collected during the summer is sufficient to enable the refinery to continue in operation throughout the entire year. The crude mineral, containing from 5 to 20 per cent of boric acid in combination with a sodium base, is shoveled into tanks containing boiling water to which is added a proper quantity of chlorine gas or sulphuric acid to decompose the alkali salts and thus liberate the boric acid. After a treatment of twenty four hours in the tank the clear supernatant liquor is withdrawn to the crystallizing vats and allowed to cool, which causes the boric acid to separate in the form of crystals, leaving a mother liquor, which is used repeatedly until it contains sufficient sodium salts to warrant a separate treatment.

The principal minerals containing boron are as follows: Sassolite, boric acid (H_3BO_3); borax (tincal), sodium biborate ($Na_2B_4O_7.10H_2O$); ulexite (boronatrocalcite) ($CaNaB_5O_9.8H_2O$); colemanite (impure varities, priceite and pandermite), calcium borate ($Ca_2B_6O_{11}.5H_2O$); and boracite (stassfurtite), magnesium borate ($2Mg_3B_8O_{15}.MgCl2$). Boron is also a constituent of several common silicate minerals, notably tourmaline and datolite. Borax, sodium biborate ($Na_2B_4O_7.10H_2O$), is the only important salt derived from boric acid. It occurs native in California, Ceylon, and Thibet, and from the last named place it is obtained in the form of tincal, an impure crystallized borax containing calcium and magnesium sulphates and chlorides and a greasy substance which is added presumably to protect the crystals from efflorescence and breakage. The tincal is purified by dissolving in warm water and adding limewater and calcium chloride in order to precipitate the grease as a lime soap. After filtering, the pure

crystals of boric acid are obtained by evaporating the solution.

Several forms of borax are used in industrial, medicinal, and laboratory processes—the principal one being prismatic sodium borate (borax, $Na_2B_4O_7.10H_2O$). There is a second variety called octahedral borax which contains five molecules of water of crystallization ($Na_2B_4O_7.5H_2O$), forming octahedral crystals. The latter variety, unlike prismatic borax, becomes opaque upon exposure to moist air and is converted by the absorption of water into the prismatic form.

A property of molten borax of great utility in analytical research is that of dissolving various metallic oxides, thereby forming transparent glasses of characteristic colors. By making a borax bead on a loop of platinum wire held in a blowpipe flame, and dissolving therein the substance under examination, the presence of certain metals is easily distinguished.

Borax is also of great value in assaying gold and silver ores, being used to dissolve and remove the base metals from the metallic lead button containing the gold and silver of the sample of ore tested. This property of dissolving oxides is utilized also in soldering and brazing metals that are oxidizable by heat; the molten borax absorbing any oxides formed whose presence mechanically would prevent the close adhesion of the metals so necessary for a proper weld or soldered joint.

Among other important uses are as a constituent of strass or paste for making glass and enamels; as a glaze for fine earthenware; in combination with shellac as a varnish for stiffening felt hats; with casein as a substitute for gum arabic, and (on account of its antiseptic qualities) as a household soap; as an ingredient of various cosmetics.

Boric acid (H_3BO_3) (old name boracic acid): In Tuscany the vapors escaping from the hot springs and from openings in the ground (fumaroles) contain boric acid, and in some places this substance is obtained as crystals by the evaporation of water from there fumaroles. The crystals or crusts produced naturally form the mineral sassolite. The crystals of boric acid are white in color, laminated in structure, and possess a mother-of-pearl luster. They dissolve readily in hot water though very slightly in cold. Upon being heated to 160° C. they lose

one half the water of crystallization and become transformed to pyroboric acid ($H_2B_4O_7$). At a red heat all of the water is expelled and boric anhydride (B_2O_3) results, which, even at high temperatures is stable and nonvolatile, and for this reason it is able to decompose nearly all of the metallic sulphates, forming when fused with them, metallic borates.

Fused boric anhydride when cold resembles ordinary glass in transparency, hardness, and brittleness. The chief uses of boric acid are in the manufacture of borax; in making colored glazes for the decoration of iron, steel, and other metallic objects; in enamels and glazes for pottery; in the manufacture of flint glass and strass or paste from which artificial stones are cut; in making Guignet's green; as an antiseptic in medicine and surgery; and as a preservative for fish, meat, milk, and other foods.

The principal methods used in the manufacture of boric acid are thus described:

In the chlorine or Moore process which is used to some extent in England, the crude colemanite in powdered form is suspended in water and heated to 70° C.; then chlorine gas is passed into the liquor and reacts on the colemanite, forming boric acid, calcium chloride and calcium chlorate. The greater part of the boric acid crystallizes out upon cooling and is subsequently purified by repeated crystallizations. The residue solution, called mother liquor, is used many times until the accumulated calcium salts begin to separate out in the form of crystals.

The mode of procedure in the hydrochloric acid process is as follows: Two parts by weight of hydrochloric acid and four parts of water (the volume of the latter being kept constant) are used, in which the calcium borate is boiled until dissolved. The boric acid is then crystallized out of the cooled liquor, leaving the calcium chloride still in solution. Before the crystals are in proper condition for packing and shipping, an additional treatment is necessary, which consists of draining, whizzing, and washing with cold water, concluding with a second and final whizzing. In Germany the hydrochloric acid process is used to extract the boric acid from the boracite contained in the famous Stassfurt salt deposits. The material

is crushed and treated with hydrochloric acid, the resultant
pasty mass is dissolved in boiling water and the solid material
separated and removed by filtration or decantation; the clear
solution is then crystallized in iron tanks, yielding pure crys-
tals of boric acid. The chemical reaction involved is ($2Mg_3B_8$
O_{15}), $MgCl_2 + 12HCl + 18H_2O = 7MgCl_2 + 16H_3BO_3$.

In the sulphuric acid process calcium borate is treated
with sulphuric acid, the reaction yielding soluble boric acid
and precipitated calcium sulphate. The boric acid is obtained
by leaching with hot water, the solution so produced being
concentrated by evaporation until the crystals of boric acid
separate out from the solution. In California the process is
slightly modified. The borate mud is boiled in huge tanks of
water containing sulphurous acid, which decomposes the cal-
cium borate, thereby liberating the boric acid in the solution
and leaving the calcium in the form of insoluble calcium sul-
phate. As before, the boric acid is dissolved by leaching with
hot water, which, however, extracts also a small quantity of
other soluble salts. For this reason fractional crystallization
is necessary in order to obtain a fairly pure product. In a few
works the insoluble calcium sulphate is separated and removed
by passing the muddy solution from the tanks through filter
presses.

The sulphuric acid process is sometimes used to decompose
the boracite of the Stassfurt deposits, and in this case Epsom
salt is obtained as a by-product from the magnesium sulphate
contained in the mother liquor, according to the following
chemical reaction: ($2Mg_3B_8O_{15}$), $MgCl_2 + 7H^2SO_4 + 18H_2O = 7Mg$
$S_4O + 2HCl + 16H_2BO_3$.

Boric acid is produced by heating in a closed vessel 100
parts of colemanite and 150 parts of ammonium sulphate.
The product of the first reaction is ammonium borate, which
is later decomposed into ammonia and boric acid. The am-
monia is condensed and collected, and the boric acid is dis-
solved from the residuum by leaching with water and concen-
trating the resultant aqueous solution until crystals of boric
acid are formed. The crystals are then removed, washed
with water until free from adhering mother liquor, dried, and
packed for shipment to the market. At times the crystals are

ground to a fine powder before being packed and shipped.

The process generally used to make borax from boric acid is briefly summarized as follows: Equal quantities of crystallized sodium carbonate and water are heated by steam in a lead lined vessel, and to the solution thus obtained sufficient boric acid is gradually added to combine with the sodium carbonate and form the borax salt ($Na_2B_4O_7$), $10H_2O$. Another process is to prepare solutions of ammonia, sodium nitrate, and boric acid in the proportions of two, one, and two, respectively. By heating this mixture and dissolving in water, borax and ammonium nitrate are formed. In both of these cases the crystals of borax are ultimately obtained by the evaporation of the solutions containing the borax salt.

At the borax refinery in Alameda, Cal., the process used to convert colemanite into borax crystals is briefly outlined as follows: The crude colemanite, obtained direct from the mines, is first broken into lumps of from three-fourths to $1\frac{1}{2}$ inches in diameter, then reduced in a grinding mill to the size of fine sand, and finally passed through rolls which grind the material to the fineness of flour. The floured product is transferred to an iron tank partly filled with water containing in solution the proper proportion of sodium carbonate necessary to decompose the calcium borate. (A ready and cheap supply of sodium carbonate is obtained from Owens Lake, Cal.) Heat is applied to the tank and the contents boiled and thoroughly agitated by means of a mechanical agitator. After a short time the chemical reaction has become completed, the double decomposition being the change from calcium borate and sodium carbonate to calcium carbonate and sodium borate. The sodium borate being soluble is extracted from the insoluble calcium carbonate by leaching with hot water, which dissolves in addition a small quantity of other soluble salts from the impurities in the ore and sodium carbonate. As a consequence the crystals of borax obtained by cooling and evaporating this solution in tanks are of a dark color and somewhat impure. They are purified by a second solution in hot water and a second crystallization in a special vat having a series of suspended wires on which the purer borax crystals form. The crystals on the sides and bottom of the vat are less

pure. The purified crystals of borax are removed from the vats, washed free from adhering mother liquor, dried, ground, and screened into several grades for the market.

At the Marion (Cal.) works the crude colemanite ore is submitted to a concentration, and the rich concentrates are shipped to the refinery at Bayonne, N. J., for final conversion into borax. These concentrates are in two forms, lumps and fines. Formerly the low grade ores at Marion were rejected, but at the present time they are heated in a two-hearth, 100-ton Holthoff-Wethey furnace, fired by six oil burners. A gentle heat suffices to cause the colemanite in the ore to disintegrate physically into a sand like product called flour, which is removed when cold by screening, and is sacked and shipped to the Bayonne refinery. One disadvantage of the separation of the colemanite by heating in a furnace is that any pandermite (the compact variety of the mineral) present in the ore is not affected by the heat, and is consequently left in the waste material remaining in the screens. At times the waste equals in quantity one half of the flour product.

The conversion of the colemanite into borax at the Bayonne refinery in New Jersey is made by decomposing the calcium borate with sodium carbonate, leaching out the sodium biborate with water, yielding a solution which is separated from the insoluble calcium carbonate by passage through a filter press at a pressure of from 50 to 100 pounds per square inch. The clarified solution is transferred to vats having wires suspended from 2-inch iron pipes extending across the top of the vat. The crystals of borax form on these wires as well as on the sides and bottom of the vat, those on the wires being sufficiently pure for all trade requirements, while those on the sides and bottom of the vat have to be redissolved and purified by a second crystallization. The pure crystals are crushed, screened, and sorted into three grades—refined crystals, refined screenings, and granulated borax. The crystals and screenings are packed for the market, but the granulated borax before shipment undergoes a final treatment, which consists of heating in an inclined rotating cylindrical furnace, crushing to the fineness of flour in a pulverizer, settling and collecting

the dust in a large dust chamber, and packing the final product for market. The Bayonne refinery is well equipped with all modern mechanical devices for the handling and treatment of the crude and finished materials.

TALC AND SOAPSTONE.

BY JOSEPH HYDE PRATT.

[Joseph Hyde Pratt, geologist and consulting mining engineer; born Hartford, Conn., February 3, 1870; graduated from the Sheffield Scientific school of Yale university; instructor in mineralogy at Yale and later at the University of North Carolina; state geologist of North Carolina, 1897–99; assistant geologist of the United States geological survey since 1900. Author of about 125 monographs and other articles on mineralogy and geology, mostly contributed to scientific periodicals.]

The name talc has been used very commonly, and yet erroneously, for a number of minerals which are similar to it in physical properties, but distinct mineralogically. Commercially, the name talc is usually applied to the fibrous and foliated varieties, which are the purer forms, and the name soapstone confined to the massive varieties. Mineralogically, the name talc refers not only to the foliated and fibrous varieties, but also to those which are compact, and soapstone or steatite is simply a variety of this mineral. Talc may be considered as occurring in the varieties, foliated and massive, with a third division known as fibrous talc, which is usually called pseudomorphous, as it has generally resulted from the alteration of the mineral enstatite. The foliated talc is the most valuable, being pure and very free from grit, so that it is suitable for use in the manufacture of talcum powders, etc. Occasionally this variety is so compact that it can be used in the manufacture of tailors' pencils, when it commands the highest price paid for any talc. Certain varieties of the massive talc are also pure enough to be ground into a flour talc, but the greater portion is used in the manufacture of soapstone articles.

The properties of talc (exclusive of soapstone) that make it suitable for the purposes for which it is used are its extreme softness, its purity or freedom from grit, its stability, and its smooth, slippery surface. Since the minerals serpentine and pyrophyllite closely approximate many of these properties, they are used to some extent for the same purposes. This is true especially of the latter, which can be used for many of the purposes for which flour talc is employed.

Talc is found very commonly throughout many of the states, and in small quantities it is very widely distributed. The steatite variety occurs more frequently in commercial quantities, but it can be worked profitably only when it is located most favorably with regard to transportation facilities and in proximity to a market for the manufactured articles. In a number of states this variety is quarried and used for chimneys and fireplaces by the inhabitants of the district in which it occurs, but it is impossible to tell exactly how much is used in this way. It has been roughly estimated that in the mountains of North Carolina from 25 to 50 short tons per year are so used.

Large deposits of foliated talc have thus far been found only in North Carolina and New York, and in both cases they are associated with limestone. Small amounts of this variety of talc are found associated with the basic magnesian rocks extending from Alabama to Canada, but in no case has it been found in commercial quantity. Where, however, the pyroxenite variety of these basic magnesian rocks has been converted into the secondary rock composed almost entirely of the steatite variety of talc, it makes a deposit of commercial value if favorably located, as mentioned above. Talc has been mined in California, Georgia, Maryland, Massachusetts, New Hampshire, New Jersey, New York, North Carolina, Pennsylvania, Vermont, and Virginia. The California talc product that was put on the market in 1902 was not talc, but a variety of serpentine obtained from Santa Catalina island, Los Angeles county. Recently, however, a deposit of talc was discovered in Tulare county, near Lindsay, about $2\frac{1}{2}$ miles east of the railroad, where it occurs in lenses of from 6 to 8 feet in width and 100 or more feet in length.

The deposits of Georgia and North Carolina are somewhat similar in their occurrence, and are probably part of the same belt, although the Georgia talc is more compact and not so fine in quality. In Georgia the principal mining has been done in Murray county. At least one half of the talc mined in this state is put on the market in the form of ground talc.

The deposits of North Carolina are found in Swain and Cherokee counties, and that portion of the belt in Swain county

furnishes the most valuable talc that is produced in the United States, and in many respects is a unique occurrence of this mineral. The quality of this talc is such as is used in the manufacture of tailors' pencils, etc., and for which there is a larger demand than can be met. All the rest of the North Carolina talc is ground to flour, and most of it is used in the manufacture of toilet powders. In Moore county occur the pyrophyllite (soapstone) deposits, which have been mined quite extensively, the product being used for various purposes. None of it is as good quality as the genuine talc, nor does it command as high a price. For foundry purposes, however, as far as can be judged, it ought to be as satisfactory as the other.

The Massachusetts talc deposits are not very numerous. The deposits of talc in Maryland and Virginia are of the steatite variety, and nearly all mined in these states is used for manufactured articles. A very small amount has been ground to a flour talc. A fibrous talc has been obtained in some quantity in the vicinity of Wiehle, Fairfax county, Virginia.

Soapstone deposits occur on both sides of the Delaware river, being found in Warren county, N. J., and in Northampton county, Pa., in the vicinity of Easton. The general width of this soapstone belt is from 500 to 600 feet, and the mineral is obtained usually by quarrying. Practically all of the Pennsylvania and New Jersey talc or soapstone is put on the market in the form of a ground product, most of which is used in the manufacture of paper.

St. Lawrence county, N. Y., is the scene of the largest talc industries in this country. The talc is of the fibrous variety, and is used almost entirely in the manufacture of paper. There are about twelve mines in this talc region, and they are located near Talcville, St. Lawrence county, and Littleyork, Cortland county. Since the consolidation of a number of the smaller properties the mining and manufacture of ground talc has been carried on more systematically and on a larger scale, thus increasing the production of talc in this state and decreasing the cost.

The mining of talc is either (1) by means of open cuts and pits, (2) by a system of shafts or tunnels and drifts, or (3) occasionally by a combination of both cuts and shafts.

The mining of soapstone (steatite) is largely by the first method. Mining by shafts, tunnels, and drifts is confined to the foliated and fibrous varieties of talc. In New York the method of mining is practically the same at all of the mines. Inclined shafts are sunk, following the dip of the country rock, which is first gneiss, and then massive white dolomite, as the beds of talc are approached. These rocks stand very well, so that timbering is required only occasionally. When the shafts reach the beds of talc, drifts are run along the strike of the deposit. On account of the compactness of this talc, blasting is usually necessary in removing it. As the talc comes from the mine it varies in size from particles no larger than dust to masses two feet or more in length, and it is conveyed in hand cars to the mills, where it is pulverized. The larger masses are broken with sledges and then passed through Blake crushers and conveyed by a belt to a pair of slightly corrugated steel rolls, which reduce the talc to small pieces, one fourth inch or less in length. From the rolls the crushed talc is carried by an endless belt conveyor to bins on the top floors of the mills, and then it is conveyed automatically into Griffin mills on the floor below. A draft of air is forced through the mill, and as the talc becomes fairly fine it is blown through an opening and falls to the floor below. It is returned to the second floor and conveyed into large hopper shaped bin cars, from which it is dropped into Alsing cylinders, in which is a quantity of waterworn pebbles, $2\frac{1}{2}$ inches or less in diameter. As the cylinder revolves, the constant pounding and rubbing of these quartz pebbles on the talc completely pulverize it. From this cylinder the talc passes through a grating, thus becoming separated from the quartz pebbles, and is conveyed automatically into a bag filling machine, where it is bagged and weighed, ready for shipment.

Talc mining in North Carolina does not present any serious difficulties, as the deposits do not extend to any great depth. The presence of water in the mines in the lowlands occasionally causes considerable expense and loss of time. Most of the mines thus located have been worked by means of open pits, which during a period of heavy rain have to be abandoned on account of being flooded. Although some of the deposits,

especially those on the hillsides, can be worked advantageously by means of open pits, the majority of them are worked to the best advantage when shafts or tunnels and drifts are used. Little blasting is necessary at any of the mines, as the talc can usually be removed readily by pick and gad. As the rough blocks of talc are taken from the mine they are hand cobbed if necessary and sorted into three grades. The larger pieces are cleaned by rubbing them with steel brushes, and the smaller ones by a founder's scouring machine. They are then dried by being spread over a floor of steam pipes, which are kept at a temperature of 212° F. When these pieces are dry they are crushed and ground by means of crushers, rolls, and pulverizers, and the foreign material removed by screening. It is then further ground in buhrstone mills, similar to those used in grinding wheat, and passed through bolting cloth which makes the final product nearly uniform in grain. This ground product is handled very much like flour, and in filling the bags with the flour talc, an ordinary flour packer is often used.

In Maryland, New Jersey, Pennsylvania, and Virginia, where it is principally the steatite variety of talc that is produced, the mining operations are carried on almost entirely in very large open cuts and pits. The preparation of the ground talc from the New Jersey and Pennsylvania mines or quarries is a process similar to that described above. In Virginia, where the soapstone is used almost exclusively for manufactured articles, the tonnage mined is of course very much larger than the weight of the articles manufactured and put on the market.

Talc is employed in the arts in two distinct forms, as powder, or flour talc, and as pieces sawed into various sizes and shapes. The flour talc is now used as a base for fireproof paints, lubricants, and many of the cheaper soaps, for electric insulators, for boiler and steam pipe coverings, for foundry facings, for the dressing of skins, and in the manufacture of dynamite, of the various toilet powders and of paper. Formerly certain varieties of clay were used as a filling in the manufacture of paper, but with the discovery of large deposits of talc, especially of the fibrous variety, in New York, talc has

largely replaced them, its fibrous and pliable character giving additional strength as well as weight. The introduction of talc in the manufacture of toilet powders put on the market under the name of talcum powders gave a new use for the more valuable talc.

The soapstone, or steatite varieties of talc, are used for the most part in the manufacture of hearthstones, linings of furnaces, for cupola and converter linings in many steel works, for laboratory tables and ovens, for laundry tubs and slate pencils, and, to a limited extent, in building. It is also used quite extensively in the manufacture of soapstone griddles foot warmers, boot driers, and for many other articles of every-day use.

ABRASIVE MATERIALS.

BY JOSEPH HYDE PRATT.

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The natural abrasive materials can readily be divided into two general groups: 1. Those which occur as rock formation and are cut and manufactured directly into the form desired, while retaining their original rock structure and appearance, as grindstones and whetstones. 2. Those which occur as a constituent of either a rock or a vein, and have to be mechanically separated from the associated gangue and cleaned, as corundum, emery, and garnet.

The artificial products would make a third class of abrasive materials, including carborundum, crushed steel, etc. The abrasive materials are so universally distributed that there are but few localities where some of them may not be found. While this is the case, various kinds of abrasives are constantly being exported from and imported into the different countries on account either of their superior abrasive efficiency or of their better adaptability to required purposes.

The use of any particular abrasive is dependent upon the character of the abrasion to be accomplished. Thus while the efficiency of a certain abrasive, as an abrasive, may be greater than that of another, it will not do as satisfactory work as one with less abrasive efficiency. For instance, although corundum has the highest abrasive efficiency of any included in the second type of abrasives mentioned, there are a number of cases where garnet, with a much lower abrasive efficiency, will give better satisfaction.

The abrasive that is perhaps the most familiar to all is the grindstone. This is produced at the present time in commercial quantities in Michigan, Ohio, and West Virginia, and in much smaller quantities in Montana and Wyoming. The

largest quantities are quarried in Ohio, whence the product is shipped to all parts of the United States. The quarries in the northern part of Ohio are located at Chagrin Falls, Berea, Cuyahoga Falls, Elyria, Euclid, Grafton, Independence, Massillon, North Amherst, Oberlin, and Peninsula; those in the eastern part of the state at Empire, Freeport, and Tippecanoe; and those in the southern portion of the state at Amesville, Belpre, Briggsdale, Constitution, Federal, Gravel Bank, Portsmouth, Vincent and Marietta. A large number of the quarries in northern and southern Ohio have been brought under one management. At Empire, Peninsula, and Tippecanoe the pulpstone variety of grindstone is found; at the quarries at Empire pulpstone is the chief production, the regular grindstone forming but a very small part of the output.

The quarries in West Virginia are directly across the Ohio river from those in southern Ohio, and are located at Atlantic, Bois, Briscoe, Lonecedar, and Sherman.

Grindstones in very small quantity have been made for local use near Columbus, Yellowstone county, Mont.; near Rawlins, Carbon county, Wyo.; and near Edgemont, S. Dak.

There is considerable variation in grindstones, dependent upon the variation of the sandstone from which they are made, which is due (1) to the character of the cementing material—whether it is a hydrous iron oxide, calcium carbonate, or silica; (2) to the percentage of the cementing material—that is, whether the grains are separated from each other by simply a minute film of cementing material or by a considerable layer; (3) to the size and shape of the grains of quartz. According to these variations there are at least seven grits that are recognized as distinctive, six of which are derived from various grades of Ohio sandstone and one from the Michigan stone.

It may be well to mention here the grades of grindstones that are imported into the United States, as they are used for special purposes for which they seem to be particularly adapted. A grindstone made from a coarse, hard sandstone is imported from Bavaria, and is used particularly for razor grinding. A fine, hard grindstone called the Craigleith, is imported from Edinburgh, and is used for special purposes in the glass trade.

Although sandstone suitable for the manufacture of grindstones is not uncommon, the variety adapted to the manufacture of a pulpstone is somewhat rare. A considerable demand for pulpstones rose when paper began to be manufactured from wood pulp. In this manufacture a stone is required that can be run in hot water. The Peninsula grit obtained from Peninsula, Tippecanoe, and Empire, Ohio, if carefully selected, ought to make a good pulpstone, which should easily compete with that imported from Newcastle-upon-Tyne, England.

The natural grindstone manufactured from sandstone was formerly in universal use in all kinds of manufacturing plants and in the household, but there has been introduced successfully during the past ten years a grindstone made from emery or corundum. While at the present time only the smaller sized grindstones for household use are made of these materials, it is possible that in the near future large wheels will be made that will rival some of the larger grindstones.

The terms oilstone, whetstone, and scythestone are used somewhat ambiguously, and often the same stone when used for one purpose will be called an oilstone, and when used for another purpose a whetstone, or even a scythestone. The term oilstone has come to be applied to all stones used for sharpening mechanics' tools, for the reason that it is necessary to use oil on most of them to prevent the stone from becoming hot and thus heating the tool, and also to prevent the small particles of steel that are ground off the tools from entering into the pores of the stone.

A considerable change is noticeable in the oilstone, whetstone and scythestone industry in respect to the stone that has the greatest use. While the sale of oilstones and whetstones has increased, or at least held its own, in the United States since 1889, there has been a considerable falling off in the sale of scythestones. This is undoubtedly due to the small number of scythes, sickles, etc., used at the present time, these having been largely replaced by improved agricultural machines and implements. Scythestones are now used in quantity only in those states or countries into which the im-

proved agricultural machines have not yet been introduced. Thus, while the production of scythestones in the United States has remained about the same, it has become necessary to seek a market for them in foreign countries, and a considerable proportion of the production is exported.

The whetstone producing rocks are all sedimentary in origin, and include quartz-mica-schist, sandstone, novaculite, and intermediate rocks. These are found abundantly in various localities, so that there are probably but few countries which have not within their borders a supply of some kind of stone suitable for making whetstones. Although the material for manufacturing whetstones is so common, only those quarries which produce stones of superior quality and have the greatest advantages for manufacturing and shipping can survive the competition in the trade. This is of course the reason the production of whetstones is confined to a few localities. Occasionally a stone is found of exceptional quality, as the novaculite of Arkansas, for which there is a large demand, although the price may be much higher than that of other whetstones. At the present time the domestic supply of whetstones is obtained from Arkansas, Indiana, Ohio, New Hampshire and Vermont. There is undoubtedly considerable whetstone material utilized in other states, but those mentioned are the only ones that have produced this abrasive for the market.

At the whetstone quarries in Arkansas, which are in Garland and Saline counties, principally at or in the vicinity of Quarry or Whetstone mountain, Garland county, there is obtained the novaculite (sandstone) from which is manufactured the best and most valuable natural oilstone or whetstone on the market. The quality of the rock varies greatly, even in different parts of the same quarry, but two distinct types of stone or grit are recognized, which are known on the market as the Arkansas and Washita. The latter is less dense and much more porous than the Arkansas. Both of these types are divided into two grades, known as soft and hard. They are used principally in the form of small wheels, oilstones of different shapes, and points such as are used by engravers,

surgeons, carvers, dentists, jewelers, watchmakers. and die-sinkers.

The sandstone of Orange county, Ind., furnishes a whet-stone known as the Hindostan or Orange stone, which is quar-ried in French Lick and Northwest townships. The stone is fine grained and is used for oilstones. It is considered the best low priced sharpening stone for mechanics' tools. A consider-able quantity of this stone is now being exported.

In Haverhill, Grafton county, N. H., and near Lamoille, Orleans county, Vt., there is a quartz-mica-schist from which are manufactured the celebrated Indian Pond, White Moun-tain, and Lamoille scythestones. These schists are variable in their structure, so that only portions or bands of them can be utilized. The cutting quality of the stone varies with the compactness of the schists and the percentage of quartz or grit contained. There are two principal grades of stone found at the New Hampshire quarries, which are known as the Indian Pond and the White Mountain. Both of these stones come from the same quarry.

At Lisbon, Grafton county, N. H., there occurs a fine grained quartz-mica-schist of a bluish chocolate color, which furnishes a stone known as the chocolate whetstone. It is a medium hard stone and is especially adapted for leather and skinning knives, and it is also used extensively for sharpening cloth cutters' tools, kitchen and carving knives, etc.

The American buhrstone and millstone varies from a sand-stone to a quartz conglomerate, which occurs along the east-ern slope of the Appalachian mountains, from North Carolina to New York, and is known by different names, according to the locality from which it is obtained. Occasionally a granite is also used in the manufacture of this stone. The states pro-ducing buhrstones and millstones in 1902 were New York, North Carolina, Pennsylvania, Vermont, and Virginia, by far the larger production coming from New York. The buhrstone produced in New York is principally from Ulster county, and is known as Esopus stone. The Pennsylvania stones, which are obtained in Lancaster county, are known as Turkey Hill and Cocalico. From Montgomery county, Va., is obtained a buhrstone which is known on the market as Brush mountain

stone.   In Rowan county, N. C., a granite is quarried and manufactured into millstones, which are sold, for the most part, in North Carolina and Georgia.

Whereas formerly a large number of buhrstones were used in the United States, principally in grinding wheat, now very few are used for that purpose on account of the introduction of the rolling mill process.

The greater part of the garnet that is mined for abrasive purposes, except the production from North Carolina, is used in the manufacture of garnet paper, which is extensively employed for abrasive purposes in the manufacture of boots and shoes.   Nearly all the production from North Carolina is manufactured into wheels, which are sold as emery wheels. The abrasive value of garnet was known to the North American Indians, who engraved shells with tools consisting of garnet points attached to wooden handles.

In Connecticut, near Roxbury, Litchfield county, garnet is obtained from a mica-schist, in which it occurs in crystals from less than a quarter of an inch to nearly two inches in diameter.   As the rock is crushed the crystals readily separate from the schist, making a clean granite concentrate, that is ready for crushing and sizing.

The principal New York garnet localities are near North river, in Warren county, and in Essex county.   The mineral occurs in segregated masses, in both, gneiss and limestone rocks varying in size from that of a pigeon's egg to that of a diameter of 200 feet.   Commercially, this garnet is designated (1) as massive garnet, when it is in the larger masses, which are impure; (2) as shell garnet, which is nearly pure garnet; and (3) pocket garnet, when it occurs in small masses or crystals in the gneiss.   Of these, the shell garnet is considered the most valuable.

The North Carolina garnet deposits that have been developed are all in Jackson county.   The principal mine is on Sugar Loaf mountain, about one and one half miles from the railroad.   The occurrences are all similar, being bands of garnetiferous gneiss in ordinary gneiss.   These bands are 50 or more feet in width, and average from 15 to 30 per cent of garnet.

The production of crystalline quartz that is included under the head of abrasives, is that which is used in the manufacture of sandpaper, scouring soaps, and as a wood finisher. In addition to these uses there are large quantities of quartz sand used in the stonecutting trade, especially by the marble workers. A small amount of quartz is pulverized, and sold under the name of tripoli.

Among the abrasives, infusorial earth and tripoli formed but a small proportion of the production, and of the amount produced less than half was actually used for abrasive purposes. Under the head of infusorial earth and tripoli are included all porous, siliceous earths of organic origin, such as infusorial earth, diatomaceous earth and tripoli, and also a siliceous material which is the residue from an impure siliceous limestone by the leaching out of the calcium carbonate. The material now produced is from California, Georgia, Maryland, Missouri, New Hampshire, New York and Virginia.

The production of pumice in the United States has been very erratic, although commercial deposits are known to occur in large quantity, especially in Utah and Nebraska. On account, however, of the distance of these deposits from the railroad, and from the large markets, they are not able to compete with the pumice imported from Lipari, Italy, which is shipped largely as ballast, and which, after being ground and bolted, is sold in New York at from 2 to $2\frac{1}{2}$ cents per pound. These Lipari deposits supply almost the entire demand for pumice.

The natural abrasives that have the highest abrasive efficiency are corundum and emery, and there is an increasing demand for these, which is due largely to the increase in manufacturing, especially of agricultural machines, but also to the improved methods that have been devised for making emery and corundum stones and wheels of all shapes and sizes. These abrasives, manufactured into wheels of various sizes, have replaced, to some extent, the smaller grindstones in manufacturing establishments. They have also been manufactured into oilstones and whetstones, and have successfully competed with the natural product, although selling at a higher price. With the exception of certain emery wheels made by the sili-

cate process, and used for saw gummers, no large emery wheels have as yet been made. Even if large vitrified emery wheels could be made, it is a question whether their cost could be lowered sufficiently to permit them to enter into competition with the grindstone, and also whether the emery stone would do as satisfactory work as the grindstone for certain kinds of grinding.

Of the corundum and emery used in the United States about one half is produced in this country, the remainder being obtained from the Turkish and Grecian emery mines, and from the Canadian corundum mines.

With the known occurrences of this mineral in this country there should be no difficulty in such production of it as to fully satisfy the markets' demand. Competition with the Canadian corundum will be strong, and if there is a decrease in price, the location of the deposits for easy mining and sufficient railroad facilities will need to be very favorable if they are to be profitably worked.

The more promising deposits of corundum in the United States are in North Carolina, at Corundum Hill, Macon county; at Sapphire, Jackson county; and at Brick creek, Clay county; in Georgia, at Laurel creek, Rabun county; and in Montana, on the headwaters of Elk creek, Gallatin county. The emery deposits are near Peekskill, N. Y., and at Chester, Mass., the latter furnishing the most of the emery produced in the United States.

PHOSPHATE ROCK.

BY JOSEPH STRUTHERS.

[Joseph Struthers, mineralogist; born at New York city in 1865, and attended the School of Mines, Columbia college (now Columbia university), graduating in the course of chemistry in 1885; for fifteen years after his graduation he was on the staff of instructors of the department of metallurgy at Columbia university; organized and conducted the first summer school in practical metallurgy of Columbia university (1896), which was at Butte, Mont. Dr. Struthers has visited many metallurgical plants in the United States and Europe, and he has carried on special metallurgical investigations; he has written numerous articles for the Engineering and Mining Journal, Mineral Resources of the United States, Twelfth Census of the United States and School of Mines Quarterly, and is assistant editor of the Transactions of the American Institute of Mining Engineers; appointed Field Assistant to the United States Geological Survey for 1901 and 1902, and in May, 1903, special agent for the United States census.]

The name phosphate is applied to the salts of phosphoric acid, chiefly orthophosphoric acid, which is a tribasic acid (H_3PO_4) and from which a great variety of salts are obtained. Each of the three hydrogen atoms in the acid can be replaced by a monad element, forming consequently, three varieties of salts, namely, those in which one hydrogen atom is replaced, those in which two hydrogen atoms are replaced, and those in which all of the hydrogen atoms are replaced. Salts in which all of the hydrogen atoms have been replaced are called ortho or neutral phosphates, while those still containing one or two atoms of hydrogen are called acid phosphates. Calcium phosphate, or more strictly speaking, tricalcium orthophosphate, is the most important of the mineral phosphates and this class forms the large mineral deposits utilized for the manufacture of fertilizers.

According to historical records, the Romans utilized the excrement of birds for fertilizing the soil, and in the twelfth century the Arabs and Peruvians used the guanos of their respective countries for a like purpose

The waste clippings of bone and ivory from the button and knife factories of Sheffield, England, greensand from the counties of Kent and Essex, England, marls from the state of New Jersey, and boneblack (spent animal charcoal) and crushed bones were used as fertilizers, at different times during the eighteenth and nineteeth centuries, but while the beneficial

results from their use were recognized and appreciated, the real cause of the stimulating effect seems not to have been definitely recognized until Dr. Justus von Liebig, of Geissen, Germany, evolved the idea that sulphuric acid should be added to bone fertilizers in order to render soluble the phosphate they contained. It was not until the year 1843 that the Duke of Richmond, after an exhaustive series of experiments upon the soil with both fresh and degelatinized bones, came to the conclusion that their value for fertilizing purposes was due to the large quantity of phosphoric acid contained in them. To prove this effect a number of vegetables were planted in burnt sand rich in every element of fertility except phosphoric acid; no development of the plant took place until calcium phosphate had been added to the sand, but after this addition the growth became flourishing.

The calcium phosphate in bones had hitherto been considered as useless owing to its insolubility, and the fertilizing element was considered to be the gelatinous matter. Shortly after 1840 Mr. J. B. Lawes put Dr. von Liebig's ideas into practice, and began to manufacture artificial fertilizers at Deptford (London) England, by mixing sulphuric acid with crushed bones. In the year 1845 Professor Henslow recommended that the Cambridge coprolites, rich in calcium phosphate, should be used as a substitute for bones in making fertilizers, and, acting on this suggestion, the numerous bone crushing works were quickly converted into chemical fertilizer and superphosphate factories. The coprolites of Cambridge were supplemented by the phosphate deposits in Suffolk and Bedfordshire, but it was not until twenty five years later that the phosphate mining industry began to assume a commercial importance. This slow growth is attributed to the supply of guano obtained from Peru, the best beds of which did not become exhausted until between 1870 and 1875. The failure of this source of supply immediately led to the substitution of other material for the manufacture of fertilizers.

In France the phosphate deposits at Grand Pre', in the Adrennes, began to be exploited in 1856, and small quantities of the rock in a ground state were utilized by direct addition to the soil. In 1865 other deposits were discovered on the

plateau of Quercy, in the department of Lot, and in 1870 the deposits in the Lot-et-Garonne, Tarn-et-Garonne, and Aveyron (known as the Bordeaux phosphates) were mined and the product sold to fertilizer manufacturers. In Spain the mining of phosphate rock began at Logrosan, province of Estremadura, about the year 1855, followed in 1860, by the exploitation of the deposits near Caseres, the latter district yielding a considerable quantity annually until 1875. In Norway phosphate deposits were mined at Kragero, in 1854, and at Oedergarten, in 1874. In Germany the Nassau phosphate deposits were discovered in 1864 and the mining of the rock commenced at once. In recent years the competition in the world's markets, of higher grade and purer phosphates from other countries has caused the cessation of the exports of rock from the Lahn mines, the material of which contains a large percentage of iron and aluminum oxides. In a few of the islands of the West Indies, notably Navassa and Sombrero, prior to 1865 phosphate deposits had been opened and the product shipped to the United States and the United Kingdom.

In the United States deposits were first worked in South Carolina in 1867. From 1867 to 1877 there was a great advance in the world's production of phosphate rock. In 1873 Belgium began contributing to the world's supply from the deposits near Mons, and France increased its production very largely. In 1880 the islands of Curacoa and Oruba, in the Dutch West Indies, supplemented the output of high grade phosphates and shipped an average of 10, 000 tons for the year.

In the decade 1880 to 1890 the sources of supply of phosphate rock altered very considerably. At the end of this period Spain, which in 1882 and 1883 shipped 100,000 tons to the United Kingdom, practically ceased to export. In France the old sources of supply had been replaced to a large extent by the newer fields in the Somme and other departments in the north. Belgium had assumed an important place, producing about 150,000 tons of phosphate from the mines at Mons alone. In the United States the South Carolina deposits had been developed to a very large extent and Florida had begun to contribute appreciably to the supply.

The various deposits of phosphatic material have not yet been classified geologically owing to the difficulty in determining the position of several of the deposits, augmented by the large number of forms which the phosphate assumes and the complex blending of certain varieties. The common technical classification makes the broad distinction between mineral phosphates, whose origin can not be traced to animal life, and rock phosphates, more or less mineralized, but directly traceable to an organic origin. On this basis the only mineral phosphates are those containing crystalline apatite, which occur in Canada, Norway, and a few localities in Spain. The deposits at Nassau, Germany, Lot-et-Garonne, Tarn-et-Garonne, and Aveyron in France, and Logrosan and Caceres in Spain are usually included in the mineral phosphates under the arbitrary and indefinite term phosphates. The term rock phosphates includes the remaining varieties of phosphatic limestone, coprolites, nodular phosphates, concretionary phosphates, arenaceous phosphates, sheet rock phosphates, and bone beds.

The value of phosphate rock in the United States lies solely in its use as a fertilizer to enrich land impoverished by continual removal of crops that have grown thereon, or land which did not originally possess the components necessary for the normal growth and development of plant life.

It has been only within comparatively recent years that the relation between plants and soils has been scientifically studied. In general the manner of life in plants resembles that of animals or man, in that they require certain foods in stated proportions which are digested or assimilated, they must breathe a certain atmosphere, and they are subject to the influence of heat and cold, light and darkness. The tissues of plants, like those of animals, are composed of carbon, hydrogen, oxygen, nitrogen, and certain mineral acids or bases, notably phosphoric and sulphuric acids, lime, magnesia, iron and potash; and the growth of a plant bears a close relation to that of an animal for the reason that it constantly absorbs elements from the soil and air to build up its structure. The relation of plant life to animal life is reciprocal. Animals breathe in the oxygen of the air and convert a small part of it into carbon dioxide, which is exhaled and returned to the air, while plants,

under the action of chlorophyl and sunlight, absorb carbon dioxide from the air and decompose it into carbon and oxygen, utilizing the former to build up the cellular structure and returning the oxygen to the air. The chief elements assimilated by plants, and consequently removed from the soil when the plants are cut down and taken away, are nitrogen, phosphoric acid and potash. These compounds play a very important part in the functions of vegetation and are the most liable to be exhausted from the soil.

BARYTES.

BY JOSEPH HYDE PRATT.

[Joseph Hyde Pratt, geologist and consulting mining engineer, born Hartford, Conn., February 3, 1870; graduated from the Sheffield Scientific school of Yale university, instructor in mineralogy at Yale and later at the University of North Carolina; state geologist of North Carolina, 1897-99; assistant geologist of the United States geological survey since 1900. Author of about 125 monographs and other articles on mineralogy and geology, mostly contributed to scientific periodicals.]

The first mining for barytes in the United States was very probably in Westchester county, N. Y., prior to 1860, and this was followed in the next decade, 1860 to 1870, by the opening of the mine at New Haven county, Conn. Between 1870 and 1880 barytes deposits had been opened in Georgia, Missouri, Pennsylvania, and Virginia, while those of New York and Connecticut had ceased to be producers. Between 1880 and 1890 Illinois had been added to the states producing this mineral, and during the next decade, from 1890 to 1900, North Carolina and Tennessee became producers, and in 1902 deposits of this mineral began to be developed in Kentucky. This makes a total of nine states in which this mineral has been found in commercial quantity. Missouri, North Carolina, Tennessee, and Virginia are producers of this mineral, with known deposits in Illinois and Kentucky, which are being rapidly developed. The Missouri deposits are furnishing more than one half of the barytes mined in the United States. They are located in Cole, Crawford, Miller, St. Francois, and Washington counties, with by far the larger proportion of the mines in the last named county. There are a number of deposits in these five counties that probably contain barytes in quantity, but on account of their distance from the railroad they are not mined to any great extent at the present time. The mineral is found for the most part associated with limestone. This rock is often altered and decomposed to some depth, leaving a residual clay-like material in which the barytes, which has resisted the alteration, is found. Sometimes the barytes is encountered close under the grass roots. The lead ore, galena, is associated more or less with the barytes,

and it makes a very valuable by-product, although occasionally a deposit is found that is practically free from this mineral. Where the barytes is encountered near the surface in the clay, it is apt to be stained more or less with iron oxide.

In North Carolina the barytes deposits occur in Gaston, Madison, and Orange counties, those which are worked most extensively being in Madison county. The mining in this state is largely by means of shafts, tunnels, and drifts.

The Tennessee barytes deposits are located in Bradley, Cocke, Greene, Loudon, and Monroe counties. The erection of a large barytes mill for grinding this mineral and preparing it for market, and also for the production of artificial sulphate of barium, and other compounds of barium, will undoubtedly lead to a considerable increase of the industry in this state.

In Virginia the barytes mines are located in Bedford, Campbell, Louisa, Pittsylvania, Russell, and Tazewell counties. The mines near Evington, Campbell county, where the mining is now carried on largely by means of shafts and drifts, have been worked almost continuously since 1874. About 1901 the deposits of Russell and Tazewell counties were opened and the latter gives prospect of becoming the largest producer of this mineral in Virginia.

The deposits of barytes that are being developed in Illinois are in Hardin county, and those of Kentucky are in Crittenden county.

The growth of this industry has been partially dependent on the growth of the paint industry, in which a very large proportion of the barytes produced is used. The barytes has a pure white color, which is permanent, and it is unaffected by weather or by gases that in some instances blacken white lead, for which the barytes is used as a substitute. Besides the use of barytes in the paint industry, it is employed in the manufacture of paper and rope to give weight; and also in the preparation of a material that is used to coat the canvas sacks in which hams are wrapped when ready for market. Another use for this mineral, and one that should increase rapidly, is in the manufacture of other barium compounds, principally the hydroxide. This compound was formerly prepared almost exclusively from the mineral witherite, barium carbonate;

but on account of its rare occurrence in commercial quantity, barytes has begun to be the raw material used in the manufacture of this hydroxide and other salts of barium. One of the greatest uses of the barium hydroxide will perhaps be in the beet sugar industry, for the separation of the sugar left in the molasses. It is also claimed that the compound is applicable in the cane sugar industry. Other uses considered for it are in the purifying of water used in steam boilers, and in the preparation of hides for tanning. As these uses of barium hydroxide increase there should be a larger demand, and consequently a larger production of barytes.

These multiplying uses for barytes put the industry on a new basis, and take the mineral out of the list of adulterants with which it has been usually classified.

MECHANICAL AND ENGINEERING PROGRESS AS INFLUENCED BY THE MINING INDUSTRY.

BY JOHN BIRKINBINE.

[John Birkinbine, president of the Franklin institute; born in Pennsylvania, 1844; educated at Polytechnic college of Pennsylvania; became assistant engineer with the Philadelphia water works in 1870, and since has been the leading American authority on this branch of engineering, having designed and constructed important water supplies, water power and blast furnaces; is expert on iron and manganese ores for the United States geological survey; president American Institute of Mining Engineers, 1891–3.]

Travelers through the country always are enthusiastic at the number of imposing mills and factories, and point with satisfaction to these evidences of development; and if a train is scheduled to arrive at an industrial center when crowds of well dressed artisans are going to or returning from their daily labor, the appreciation of the value of these industries to the workingman and to the state is emphasized. But journeys through mining districts, as a rule, offer fewer evidences of great achievements; for beyond the head and power houses or the breakers of mines, stocks of mine timber, rows of miners' cottages, and, in some cases, great piles of mine refuse, there is little on the surface to indicate what is being accomplished; and it is only occasionally that the mine openings are located near enough together to permit of any considerable concentration of working forces. Even if the miners are seen en route to or from work, the division of labor into shifts of from eight to twelve hours each, and the necessity of lifting the miners in small companies from below the surface, usually prevent any large assemblage of workmen. There are exceptional mining localities where a number of shafts are close together, and hundreds of men and boys may be seen at one time, but even in these instances the grime of the underground life has a tendency to detract from the effect upon the general observer.

Thousands of miners toiling deep in the earth's strata are not only lost to sight, but generally entirely forgotten by the public, until an Avondale fire, a Twin shaft cave, or an explosion, sacrifices such a number of lives as to appall the com-

munity and direct attention to the work of the human mole.

If we fail in an appreciation of the extent of the mining industry we are equally at fault in recognizing the influence which it exerts upon our development. The utilization of 150,000,000 to 175,000,000 long tons of coal, annually won from American mines, for industrial and household purposes, may, perhaps, be approximately gauged; or we may measure the advance in wealth due to the exploitation of the minerals each year to produce 55,000,000 to 60,000,000 ounces of silver, 2,000,000 to 2,250,000 ounces of gold, 350,000,000 to 400,000,- 000 pounds of copper, 170,000 short tons of lead, 90,000 short tons of zinc, quicksilver to the amount of 36,000 flasks, more than 500,000 to 1,000,000 pounds of aluminum, 53,000,000 barrels of petroleum, 8,000,000 to 9,000,000 barrels of cement, 11,500,000 to 13,000,000, barrels of salt, clays valued at $10,- 000,000, $35,000,000 of building stone, and $13,000,000 worth of natural gas. But this impressive array of figures does not convey a just idea of conditions, and few truly realize what has been and what is being done by the mining industry to advance our nation.

To assist in forming a conception of the progress for which the engineering profession and the mechanic arts are indebted to this industry, attention may be directed briefly to some of the achievements which may be justly credited to the underground exploitation of our mineral resources.

Mr. Eliot Lord, in his monograph, Comstock Mining and Miners, writing of that section of the state of Nevada which has produced gold and silver to the value of $380,000,000, says: "Such is the nature of the region bordering upon the eastern slope of the Sierras, and such the character of its savage inhabitants, that forty years ago no territory in America seemed more unlikely to attract a swarm of colonists. Except along its northern boundary, there was nothing to tempt the entrance of the intrepid fur trader, and even the undaunted Jesuit missionaries contented themselves with maintaining the white crosses of their stations on its border line. Thus the outside world knew and cared to know but little of this broad and seemingly worthless tract, and the homes of the basin tribes would have been secure from intrusion to this day had

it not been for the discovery of the treasures hoarded up in the barren ridges and canyons.   The train of emigrants which crossed the plains in the year 1849 had no eyes to see the possible riches of the land through which they were passing, for their faces were set steadfastly toward the glittering beacon beyond the Sierras."

The Comstock lode is selected as an illustration, because its development rapidly transformed a desert mountain region, distant from any settlement, into a populous business center, supplied with superb evidences of engineering skill. The character of the ore won was the inspiration which developed some of the best forms of crushing appliances; the depth of workings, the size of deposits, the quantity of water to contend with, and the extreme heat of the lower workings demanded the construction of superior hoisting, ventilating and pumping machinery; the square set system of timbering (without which many other deposits could not now be successfully exploited), the construction of a drainage tunnel which is world famous, and other innovations, resulted from the developments on the Comstock lode.

The migration in 1849, of seekers for gold, opened up the wealth of California, and that state is entitled to credit for many advances in hydraulic engineering devised to maintain its mining industry.   Immense dams, long and tortuous canals or flumes, the cutting away of great masses of earth by streams of water delivered through Little Giants under heavy pressure, the diversion of streams, so as to work their natural beds as placers, and the construction of impact water wheels, operating under heads of water which previously had been considered impractible, are some of the results of mine developments.   Colorado may well share in this credit, for it has extensive mining tunnels, elaborate water power installations, etc., but in that state the construction of railroads in deep canyons or over high mountain passes, to reach the mines and convey their output to market, is probably considered the most notable feature.   Montana, Oregon, Arizona, Utah, and in fact the entire mountain and Pacific sections of our great west, present numerous instances of progress due primarily to the development of mineral properties, and the mining industry

is undoubtedly largely responsible for the early completion of our transcontinental railroads.

The exploitation of iron and copper ores of the Lake Superior region has been a most potent factor in the material advancement of that district, and in the development of the lake marine. The depth of these mines, the quantity of material handled, and the distance from points of consumption and from fuel supplies, have inspired the mechanical engineer to design hoisting, pumping and concentration plants second to none, and the marine engineer to supply vessels of superior construction and equipment.

The new south also owes its present advanced position more to the exploitation of its mineral wealth than to any other feature.

Coming nearer home, we may properly ascribe the construction of the canal system and the earlier railroads to the necessity of conveying the output of our coal mines to market, and of handling economically in large volume raw materials to, and the products from, furnaces and mills, and the preeminence of Pennsylvania as an industrial state is directly traceable to the utilization of its stores of fuels, ores, stones, and clays.

The exploiting of mines, therefore, has not only called into play the ability and energy of the geologist and the mining engineer, but has demanded also the best efforts of the metallurgist, the mechanical engineer, the electrical engineer, the civil engineer and marine engineer, to supply drilling, hoisting, ventilating, pumping and beneficiating machinery, or appliances for handling and transporting the product by land or water; and has called on the chemist for the analyses of minerals, metals or gases and for the production of explosives. These specialists have been able to accomplish the desired results by placing the execution of their plans in the hands of intelligent mechanics, and to such artisans we are indebted for many of the mechanisms which to-day make cheap mine handling and transportation possible, and which permit of transforming the materials won from the earth into forms applicable to general use.

It is only when one descends into mines and notes the great chambers dug out of the earth, the quantities of timber placed to support, as far as is possible, the weight of roof or hanging wall, the massive pumps which elevate enormous volumes of water from great depths, and the powerful hoisting and ventilating appliances, that the magnitude of the mining industry is appreciated. When he investigates further and notes the drills penetrating the hard rock, or the cutters channeling below the mass, or locomotives traversing the low, narrow drifts operated by electricity or compressed air, generated at some distant point, the aid of the mechanic becomes apparent.

The dip compass, the prospecting drill, the sinking pump, the steam winch, the rock drills, the crushers, the coal cutters, the chutes and the tram cars, the framing of shafts, mine timber, head houses and breakers; the conveyance of steam, water, air, electricity for power in hoisting, tramming, pumping, etc., the rails, locomotives, cars and loading bins; the shipping and receiving docks for coal and ore, and the vessels built for their transportation; the machinery of concentrators, breakers, the buddle rocker, the vanner, jig, and stamps, etc., the blast furnaces, converters and roll trains, with their motive powers, all represent developments in the mechanic arts.

The influence of the mining industry can be thus demonstrated to have extended into all branches of the mechanic arts.